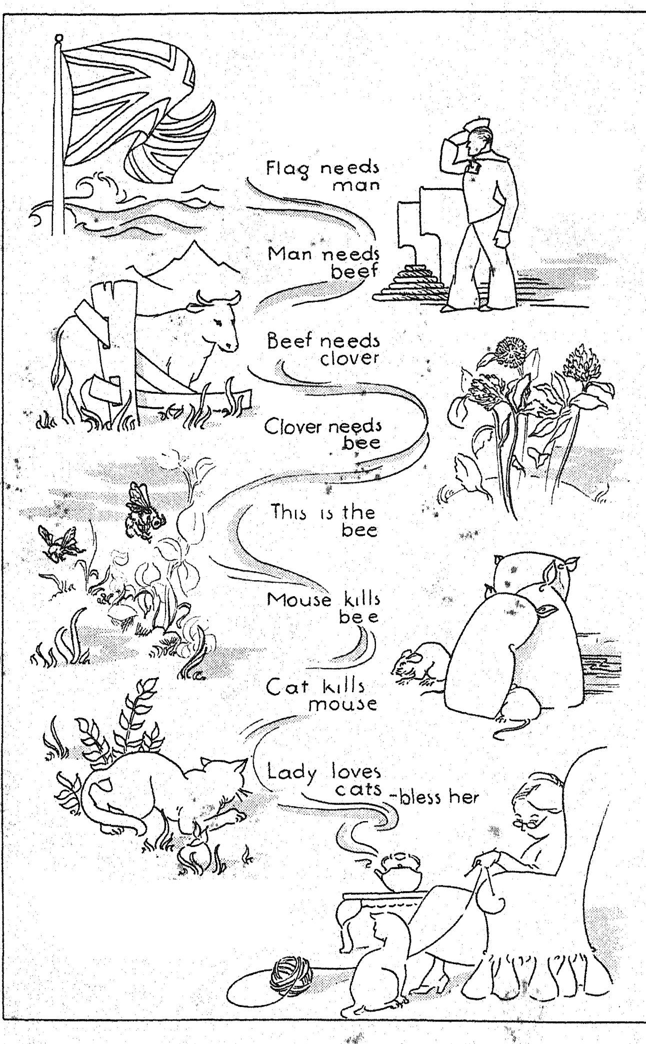
THE SCIENCE IN MODERN LIVING SERIES

Basic Science Material for Use in Modern Education

SAMUEL RALPH POWERS, *Editor*



Cats, Mice, and Bees. Cats, Birds, and Bugs?
. . . Ah, That's Another Story!

Life and Environment

THE INTERRELATIONS OF LIVING THINGS

BY

PAUL B. SEARS

Professor of Botany, Oberlin College

Bureau of Publications

TEACHERS COLLEGE : COLUMBIA UNIVERSITY

NEW YORK MCMXXXIX

PRINTED IN THE UNITED STATES OF AMERICA
BY THE HADDON CRAFTSMEN, INC., CAMDEN, N. J.

EDITOR'S INTRODUCTION

THE Bureau of Educational Research in Science, in which this volume has been prepared, was authorized by the Dean of Teachers College and established in September, 1935, to initiate and carry forward studies in the teaching of science. It was made financially possible by a grant from the General Education Board and it has been assisted in its work by the cooperation of various public schools, colleges, and universities that have given leave to certain members of their staffs to work on phases of the project. The Bureau has been advised in its various activities by a committee appointed by the President of Columbia University from the Graduate Faculties of the University. Experts from the fields of science, mathematics, the arts, the humanities, social studies, and from the more specialized fields of psychology, sociology, school administration, and education have met from time to time to counsel informally with members of the staff.

Interests of the Bureau have been centered in a program of science teaching designed to contribute to general education; that is, one in which content of the curriculum and methods of teaching are chosen because of their immediate significance for human living. These interests have carried us beyond the program

of science teaching as it is usually conceived, for we cannot think of science in general education as something apart from other aspects of the curriculum. Tradition and preparation for college have dominated both content and method in the curriculums of the past. It is not contended that curriculums so dominated are necessarily bad in whole or in part, especially when considered from the point of view of the purposes for which they were designed; rather it is contended that curriculums consciously planned to contribute to general education will better serve that end than those in which such a contribution, if present at all, is a by-product.

The studies in progress, several of which are nearing completion, will result in reports of two types. There will be a series of publications dealing with basic science materials bearing upon important situations and problems of modern living. These will include: *The Storehouse of Civilization*, dealing with resources and how to use them to maintain a continuously on-going society; *Scientific Method*, giving a coherent picture of the world as revealed by science and suggestions for the use of the methods of science in meeting the problems of living in it; *Biological Production and Control*, relating knowledge to the physiological and economic welfare of mankind; *Human Growth and Development*, interpreting the physiological and psychological changes that occur during the life span; *The Physical Sciences in General Education*, a

contribution to understanding of how ideas concerning the physical universe emerge in thinking; and others.

The second type of studies is closely related to the first and is concerned primarily with processes and outcomes in teaching and learning. These publications will be under the general title of *Suggestions for Teaching*, and will illustrate the manner in which basic science may be used to help young people to deal with their problems, interests, and needs. Typical of this group is a report entitled *The Life Span*. It employs basic science from *Human Growth and Development* and from other sources. It is a plan for teaching and for the study of the changes—intellectual, emotional, and aesthetic—that occur in young people as they use our cultural resources in dealing with the physiological and psychological problems that come into consciousness as the span of life passes. The publications of this type will include: *Resemblances and Differences between Parents and Offspring; The Selective Exchange of Material and Energy between Living Things and the External World; The Physical Universe and Its Changes through Time; The Control of Infectious Disease; The Use of Materials from the Earth's Crust; The Control and Use of Energy;* and others.

This volume, *Life and Environment*, is the first to appear in this series of basic science materials. It is an interpretation of situations and problems arising out of the interrelations between human society and its living and nonliving environment. Man has the capac-

ity to understand these interrelations, and in this respect is unlike other organisms. He has the hope and indeed recognizes his responsibilities for controlling them. This industrial society in contrast with that of primitive peoples has been produced through human ingenuity. Man must continue to exercise his ingenuity if he is to maintain and advance his present achievements.

This volume presents in broad relations a survey of man and his society. Plants, animals (including man), soil, air, rain, heat, cold, fire, wind, are compounded into a comprehensive and ever changing world-picture. In viewing this picture the reader may identify the changes in progress and in turn may direct his efforts so as to advance those that are constructive and so as to arrest those that are destructive. It is only in some such setting as this that we may deal effectively with problems of conservation and use of our resources. The development of some such world-view and the inculcation of abilities, ideals, and attitudes appropriate to the maintenance of our society is a leading aim of general education. This volume is offered as a most significant contribution to the furtherance of this aim.

The author, Paul B. Sears, is a recognized authority in the field of ecology and a pioneer in the application of ecological methods to the study of man and his social organizations. Many who peruse this small volume will be interested in extending their reading to include some of his research papers and also some of

his popular works in which, writing in a lighter vein, he has offered to the general public an interpretation of the interdependencies between human society and the general environment with which it is interwoven.

This and the volumes which are to follow will no doubt be of interest to laymen who are students of public education. They have been prepared especially for curriculum workers and for teachers of science and of other subjects, in an effort to help them to serve with increasingly greater effectiveness the young people that society places in their charge.

SAMUEL RALPH POWERS

Acknowledgments

My gratitude is due the University of Oklahoma for generous grants of leave during preliminary work on this manuscript; also to my colleagues in the Bureau of Educational Research in Science, Teachers College, Columbia University, for their constant help. Many individuals have assisted with suggestions. In particular I am indebted to Professor Emeritus Frederick O. Grover of Oberlin College, Professor E. W. Sinnott of Columbia University, and Mr. J. G. Manzer of Trenton (New Jersey) High School, for invaluable criticism.

Paul B. Sears

CONTENTS

Foreword

How can an understanding of life and environment affect our daily lives?

The materials to supply our physical needs and wants come from our environment, and so does the energy whereby such materials are fabricated and distributed. The problem of meeting these needs is suggested by such phrases as "employment," "cost of living," and "standard of living." We depend upon the presence of necessary materials and energy sources in our particular environment, and upon the social processes—part of our living environment—through which we make such material and energy available.

Many of us were born in villages which we have left because of "lack of opportunity." The nature of this lack becomes clearer when we realize that many of the communities in which our grandparents were born have disintegrated and can no longer provide the physical means to support the populations they once did. The great westward movement of population in North America, now ended, is familiar to all. Was it caused only by increasing population in the East, spurred by the restlessness of returning soldiery at the end of our several wars? Or was it in no small measure due to a gradual depletion of the more eastern

environment as well? Certainly there is a definite relation between eroded and depleted farm soil, changes in farm occupancy, and westward migration. One may begin a study of this relationship equally well among the overgrown stone fences of New England, or the gullied clay hillsides of Georgia.

Our political representatives are unceasingly confronted with the rural problem in some phase or other. This began as "upstate versus downstate" in places as widely separated as New York and Alabama. Today it has burgeoned forth into "crop control," "farm relief," and the "tenant problem." Less obvious phases are the cost of city living and widespread malnutrition, in both city and country. Plainly neither urban nor rural populations are getting what they need from the land in any permanent sense.

Visible oil supplies are nearing an end, variously predicted but certain. Newspapers have recently increased in price in many places, the reason assigned being that increasing scarcity of wood pulp has made paper more costly. Whether this is fact or pretext, at any rate there can be no doubt that we are using wood much faster than it is being grown. Lumber and other forest products are priced exorbitantly, in regions which less than a century ago faced the problem of getting trees off the ground to grow crops. Rivers are muddied and bays choked, while lakes and reservoirs, often the result of costly damming, are being silted up. Largely this silt represents what has been good pro-

ductive soil, or worse yet, the foundation upon which such soil has lately rested. Practically one third of our original topsoil is gone. Fish, game, and needed recreation areas have largely disappeared.

The great western cattle range, a magnificent natural pasture, has been broken by the plow, or set back through too heavy grazing. In many places it has been reduced to desert by those human activities which accelerate washing or wind erosion, or not infrequently both. The water table of our continent has dropped many feet and the quality of water obtainable by well-drilling has become in many cases inferior. Floods are becoming more frequent and certainly more disastrous; and dust storms are now recurrent events, with attendant damage to health and property.

In the field of international relations, the free movement of materials from the place of cheapest, most efficient production is pretty thoroughly blocked. We subsidize the production of sugar in temperate climates and hamper its importation from the tropics. Increasingly we use materials and energy to prepare for war, whose result is to intensify the destruction of environmental balance.

These are a few of the evidences of bad adjustment between man and environment; they affect us all. The study of such situations falls within the province of ecology, or the science of life in all of its relations to environment. A knowledge of the findings and the conclusions of ecologists is essential if we are to view

our present difficulties in proper perspective, and provide a scientific approach to their solution. It should be clear that the ultimate aim of applied biology lies in a better adjustment of man to his environment, living and inanimate. In whatever way this social end is achieved, whether by social means, through the power of public opinion, or by individual action, it must be based upon ecological knowledge. Such knowledge must always bear a close relation to enlightened political behavior. And so, in a democracy, we are justified in believing that the principles of ecology ought to be a part of the common working knowledge.

Life and Environment

The Interrelations of Living Things

CHAPTER I

LIFE AND ENVIRONMENT INSEPARABLE

Life and Environment Are Inseparable Except for Purposes of Analysis

---

FOOD, FOR EXAMPLE, COMES FROM THE ENVIRONMENT

SUPPOSE we start with the very practical and familiar question, to wit, "When do we eat?" The simplest, most obvious answer is that we eat when we are hungry, if there is food to be eaten; assuming, of course, that we have the means to pay for it, or to secure it somehow. We may count on the recurrence of hunger so long as we live; we cannot dismiss the problem of food so simply.

Hunger, although it may be sharpened by what we see or smell, comes from within. Food comes from without, that is to say, from the environment. Thus, in the sheer business of staying alive, we are related to environment in a way we cannot avoid. Within this environment, the source of our food is mostly material from the bodies of plants and animals.

The kinds of plants and animals which are available for our food vary from place to place and from time to time. This variation is frequently due to climate, but it may also be due to changes in the earth's pattern of

land and water and the accompanying evolution and shifting of life. The abundance of plants and animals, and thus of food, may also vary. Other things being equal, the better the supply of moisture and the higher the temperature, within certain limits, the more life there is. But other things are seldom equal, either with place or with time.

We try to overcome the inequalities of the environment by selecting and manipulating the kinds of plants and animals we find most useful for our needs. We first have to remove those which are not desired and which grow without our assistance. In so doing we change the environment. Presently we discover that we have done more than substitute our domestic plants and animals for the wild kinds. We must reckon, for example, with the fact that we have modified or even destroyed the very essential process of soil formation. Soil has arisen through the activity of the native vegetation and animals, which have transformed materials both by constructive processes and by producing decay. Upon soil depends earth's capacity to produce life, and so to produce food for us.

Our domestic plants and animals are seldom so well adjusted to the variations of climate as were the wild kinds which they have replaced. They have been developed in such a way as to require very special protection and care; abandoned fields seldom show any survivors from preceding crops. Domestic forms are

subject to wholesale epidemic because of their abundance and the fact that they are very often especially nutritious to lower organisms which produce disease. Furthermore, we come to depend upon a relatively few selected kinds and should they not thrive, we may go hungry.

SOCIAL ENVIRONMENT AFFECTS FOOD SUPPLY

Again, some of us live in cities, without access to the land on which our food is grown. Many of us do not have the knowledge and skill required to produce food, even if we do have the land. Those who work the land may not require the services which we in the cities have to exchange for the food they grow. Or quite as serious, they may require our services as badly as we require the food; but the social mechanism of exchange may prove defective, as it often does. Now that there are railroads in India, for example, food can be moved into a province whose crops have failed; but the hungry face a new problem as deadly as that of the old days of famine. Wherewith, in their poverty, can they purchase from this abundance?

Yet we may ask why, if they are starving, the food is not theirs for the taking? The hungry savage is free to snare any wild fowl he sees, or catch the fish from any stream, or even to eat his grandmother. What is there to keep the modern from acting likewise? We say the food is not his unless he buys it; and to understand that, we must remember that even the savage

might go hungry rather than eat, say, a cat, or perhaps a beaver, or some other animal which he and his people agree must never, under any circumstances, be eaten.

The reason for this belief, or its wisdom, does not concern us here. It will serve our purposes to know that the savage has it because he grew up among people who entertained it. We in our turn believe in the institution of private property because we have been bred among those who share this belief. It is, of course, only a belief, and not always a strong one at that. But it does very effectively influence our relation to environment in this simple matter of getting food when we are hungry—aided, of course, by restraints set up by those who believe likewise. It is not visible physically, as the soil and the plants and the people who go to make up our environment; but the effects of such a belief are quite visible and tangible, in terms of human behavior.

LEVELS OF ENVIRONMENT

As we have talked about this matter of food as simply as we could, we have seen several phases, or levels, if you prefer, of the environment coming into play. Earth and atmosphere (together with the light of the sun) make possible the growth of plants. Upon these plants animals are fed, and we in turn obtain food from both. But the handling of these sources of food and the distribution of it are matters of human cul-

ture.[1] And these processes of culture are quite as much a matter of environment for the individual as are the wind, the rain, and the corn plant.

This is the sun that shines in the sky
This is the soil that lay in the sun that shines in the sky
This is the corn that grew in the soil that lay in the sun that shines in the sky
This is the ox that ate the corn that grew in the soil that lay in the sun that shines in the sky
This is the farmer that slaughtered the ox that ate the corn that grew in the soil that lay in the sun that shines in the sky
This is the burgher that paid the farmer that slaughtered the ox that ate the corn that grew in the soil that lay in the sun that shines in the sky—and that is how the burgher came to eat sunshine.

(With apologies to some ancient and beloved rhymester)

[1] The word "culture" is used throughout in the sense employed by the modern anthropologist. Cf. Webster's International Dictionary:

5a. "A particular state or stage of advancement in civilization or the characteristics of such a stage or state."

5b. "The complex of distinctive attainments, beliefs, traditions, etc., constituting the background of a racial, religious, or social group."

Phrases used in this sense are

Culture area	C. mixing	C. sequence
C. center	C. pattern	C. stage
C. complex	C. phenomenon	C. trait etc.

STUDY OF ENVIRONMENT INVOLVES ENTIRE RANGE OF SCIENCES

Soil and atmosphere we understand largely, but not wholly, in terms of the physical sciences; but we are more and more coming to see that soil is a resultant of the interaction of life and inanimate factors.

Plants, animals, and man are studied in terms of the biological sciences. Yet biology invokes the physical sciences at every turn to explain the development and behavior of living things. The activities of the central nervous system of man—that is to say, of his brain—give us the subject matter of psychology and the social sciences. Much that these sciences deal with can be cleared up with the aid of physical and biological science. Yet the mental activity and social behavior of human beings present many facts as yet not commensurable with the subject matter of physical and biological science, whatever our hope for the future.

Our relation to environment presents problems at every level of the natural sciences, runs through the social sciences and on beyond them into the rarefied air of the humanities. Here in history, philosophy, and the arts, man is compelled to wrestle with the insistent problems of the good, the beautiful, and the true, using the technique of the artist rather than the symbolism of impersonal science in an effort to examine and convey the values which are embodied in his interrelations, as he sees them in the light of experience.

Yet while the humanities differ thus in purpose and technique from the sciences, both must work in terms of the culture which they represent. And the humanities have an exceedingly important function in relating man to his environment, for they take up the problem where science must, perforce, leave off. If they are conceived in a spirit of isolation from the currents of science, they are likely to be sterile in the modern world, however beautiful or satisfying they may be in the abstract. There may be legitimate argument as to what the humanities ought to do; there is no question as to what they can do.

INTERRELATIONS OF THE CURRICULUM

In the past the various courses of study in our schools and colleges have too often been taught as more or less closed subjects within themselves. This is the attitude of "pure" scholarship, fostered by the universities and working downward through the educational system. I can speak with some feeling about this matter. In the case of my own subject, botany, secondary school teachers have been going out since 1885 unable to do much better than to re-echo their university work; and as a result their instruction has had so little significance in the schools that it has largely been kicked out. Meanwhile, their fellow students who went on into research have succeeded beautifully, and have produced results of the greatest value to society.

Increasingly, however, it has proved difficult to maintain purity, in the sense of isolation, of any scientific subject. It is no longer expedient in research, certainly. The greatest vitality at the present time lies in fields intermediate between the older subjects. This is true, for example, of physical chemistry, biochemistry, and biophysics, whose names indicate their borderland character; but it is also true of genetics and ecology, which transcend the old boundaries between zoology and botany and make technical demands beyond the field of biology itself. The geneticist is speedily involved in mathematics, the ecologist likewise, not to mention his need for scientific knowledge of atmosphere and soil.

The difficulty of isolation becomes greater as we move to the higher and more complex levels of subject matter. Yet, considering science teaching as an end in itself, apart from research, there is still a large amount of it that is defective because of too great isolation from other technical fields which have become essential to a proper understanding of a particular field. Thus a knowledge of physics is essential to the student of physical chemistry; yet it sometimes happens that students enter the course without such preparation. And special students of geology often undertake the study of fossils with little or no knowledge of biology, which is no small handicap.

This isolation of science courses is a matter of great practical concern in everyday living and thus in gen-

eral education. For if the teaching of sciences in isolation is bad for the professional, it is worse for the general student, who must depend upon his science courses to give him not only an understanding of procedure but a picture of the world in which he must live. The net effect of his experience with the usual isolated science is not to increase but to destroy his sense of its concern with the reality of everyday life.

A strong case can be made for the progress of science as a response to specific and growing human needs, although it should not be forgotten that the pure scientist can make a good case for science as an adventure of the human mind, with practical consequences following in its wake. Certainly the pursuit of science has the same individual justification as any other human activity.

This, however, need not detain us. The fact is that the modern world has been completely transformed through the applications of science in human technology. This modern world cannot be lived in with any intelligent participation unless the nature of these changes and the agencies which have produced them be understood. They are understood and used by those who wish to control affairs for their own ends; the only restraint on such control is a measure of understanding on the part of the public. Science can be an extremely potent instrument of misrule—none more so. It had much better be made a means toward justice and abundance.

Opinion and practice may differ as to how far the scientist should, in his teaching, develop the applications and consequences of his subject to human society. It may be urged that this task belongs to those who teach about society. One thing is certain—the pupil must be made aware of what science is and how it can be used. And he cannot become so, unless those who teach him are all vitally aware of these facts. And this awareness must apply not only to what has been done but to the possibilities which science holds for future adjustment between man and his environment. It is essential that the teacher of science not only know how to use the tools at his command but that he know these tools to be powerful forces, either for good or for evil. It is quite as essential that the teacher of the social sciences, and indeed of the humanities, have much more than a vague notion of the procedure, the scope, and the possibilities of science. There is at present all too much lip service in these quarters. The resulting damage is plainly registered in modern political administration, where the scientist is still looked upon as he was by Napoleon—an individual to be seen and used, but not to be heard.

SUMMARY OF ENVIRONMENTAL RELATIONSHIPS

Before any general facts are presented, it will be helpful to attempt an extremely concise perspective of life and environment.

Plants, being able to manufacture food from the

environment, are necessary to the support of animals, while man is dependent upon both. The earth, when man entered it as a new species, had gone through a long process of evolutionary change, resulting in practically its present fauna and flora. Biologically, man is adjusted to life in a complex environment. He has the benefit of a world developed by ages of change.

Man, by his mental activities and the resultant social organization, has still further modified this environment. For the most part he has done so in response to direct needs, and without regard to the intricate balance of activities which rendered the earth fit for him in the first place. He has become the dominant species of the earth—the first and only species so widely dominant, so far as is known, in its history. Because of this fact and because of the new levels of psychic behavior which are his there arises a group of very special ecological problems. Man must work toward a new equilibrium of nature fitted to his own survival. Physically, he is practically the same animal he was in the earliest stages of his culture. The plants and animals with which he works, while highly selected and improved, remain plants and animals. There is no reason to suppose that he can establish any permanently favorable balance with nature while ignoring the laws which govern the general relations of life and environment. It is therefore important to know these laws, so that man may understand the world and make it a suitable abode for himself.

CHAPTER II

Advancing Human Culture

The Development of Our Knowledge of Environment Is a Phase of Advancing Human Culture

---

AUTHORITY AND PROOF

For most of us, the source of knowledge is an important matter. To carry conviction, religious knowledge is authenticated as coming directly from divine sources. That places it beyond questioning, and worth dying for, even in the face of other knowledge claiming equal sponsorship. With scientific knowledge, while we are interested to know from whom it comes, we find it much more important to know exactly how the knowledge was obtained. Knowing that, we can go over the ground and test matters for ourselves, provided, as is too often not the case, we are willing to take the trouble.

PRIMITIVE KNOWLEDGE OF ENVIRONMENT

Accordingly, before we go much further, it seems important to see something of how life and environment have been studied. That ought to give some solid sense of reality when we begin talking in general terms about what is known. The electromagnetic the-

ory of light and the modern radio are much more reasonable matters if one reads of the simple experiments performed by Benjamin Franklin and Joseph Henry and some of their European contemporaries. It is wonderfully helpful to know what can be done with an electric battery, some coils of copper wire, and a galvanometer needle.

In the same way, let us look at the homely beginnings of our knowledge of life and its environment, and see how this knowledge grew. Man at primitive levels of culture knew the plants, animals, topography, and weather as a modern farm boy knows his countryside. Largely he knew them for the same reason, too; like the farm boy, he was at once part of the scene, and yet able to read what was about him. Modern man has yet to experience the discovery of a single food or drug plant whose uses were not known in some measure to primitive people. This fact alone indicates the thoroughness with which the flora was explored long before the formulation of the scientific method by Francis Bacon in the seventeenth century.

There is considerable evidence from scientific collectors that natives whose connection with the traditional lore of their own people has not been broken make invaluable field assistants. They are often capable of making sharp distinctions between plants, often indeed having names for a large proportion of those in their vicinity. Moreover, they know the kind of habitat in which certain desired materials are to be

found. In the case of animals they have that knowledge of the feeding, breeding, and nesting habits so essential to the hunter. And they have their own means of measuring the flow of the seasons and the changing pattern of life.

In other words, the contact of primitive man with his environment is immediate and direct. He knows a very great deal about it at firsthand, in terms of his own symbols, to be sure; and the culture of which he is part is largely concerned with the natural landscape about him. These physical and biological realities must, of course, play a large part in the shaping of every primitive culture. But we must not forget that other factors enter the picture—surviving culture traits developed in earlier environments, transfers from other cultures, etc., besides human unpredictability!

THE SEARCH FOR EXPLANATIONS

One notable characteristic, even of primitive man, is his search for explanations of what he experiences in nature. These explanations possess one element in common with modern science. They aim at being consistent with the simple experience and cultural environment of the group which develops them. To us they often seem like the crudest superstition, but they represent the germ from which science has developed. From them come the terms in which the primitive man thinks of the environment about him, and the at-

titude which he adopts toward it. This suggests in some measure the importance of a man's human environment in modifying his relation toward the wider general environment. This importance grows with the development of human culture and the steady loss by the individual of responsible contact with nature.

As higher levels of culture are reached with agriculture, cities, and writing, some aspects of the environment have to be dealt with rather seriously and methodically. We see astronomy and the calendar as instruments of travel, orientation, and record-keeping. Geometry arises and surveying becomes possible. Simple mathematical calculations are devised to regulate commerce among men. What is known concerning plants and their uses is committed to writing for the reference of medical men.

EARLY RECORDS OF NATURAL KNOWLEDGE

It will be found interesting, in this connection, not only to look up the early history of astronomy, medicine, mathematics, but to consult the *Works and Days* of Hesiod.[1] Written probably in the eighth century B.C., as an almanac, it gathers together a lot of assorted useful information about seasons, farm operations, wild animals, simple household medicine, etc., among the Greek farmers. The story of the Mayan calendar and temple design in relation to astronomical

[1] Hesiod. *Works and Days*. Translated by George Chapman, Library of Old Authors, 2nd ed., John Russell Smith, 1888.

date-fixing, as worked out by Morley and others, is also to be recommended.[2]

With early beginnings of so much promise the question naturally arises: "Why did not science—the simple, common sense verification of events in nature—develop long ago?" We probably could answer that with a little searching and honest examination of our own experience. What proportion, actually, of the knowledge which guides our daily actions comes from our own direct observations? Not much truly. Where does it come from then? Why, from what we hear and read and learn—in other words, from the culture about us—not from things themselves. Although, living as we do in a technologic world, we are forewarned that much which comes to us in this way needs to be checked, yet we seldom question it. For practical purposes our cultural environment still remains the chief and most convincing source of knowledge for most of us.

CONFLICT BETWEEN OBSERVATION AND CULTURAL TRADITION

Small wonder then that our ancestors allowed observation and cultural information to mingle freely.

[2] Morley, S. G. "Foremost Intellectual Achievement of Ancient America; Hieroglyphic Inscriptions of Mexico, Guatemala, and Honduras." *National Geographic Magazine*, Vol. 41, pp. 109–134, February, 1922. "Unearthing American Ancient History." *National Geographic Magazine*, Vol. 60, pp. 99–126, July, 1931. "Yucatan, Home of the Gifted Maya," *National Geographic Magazine*, Vol. 70, pp. 590–644, November, 1936.

They still felt the need of consistent explanation, true. But if the results of direct observation and culture came into conflict, the latter frequently carried the day, as it does even now. What else can we say about present-day drives against "non-Aryan science," "capitalistic cannibal traitors in science," and even a lot of "democratic" drivel about the equality of man on the one side, and eugenic nonsense on the other? Ligation of the *vas deferens* to make a man sterile really sounds more scientific than chopping off his head, but the practical end sought may be the same.

Even for Aristotle, marvelous naturalist that he was, the cultural heritage was too much. Conditioned to work in the Platonic manner, he was crippled in his efforts to discard it. He saw nothing wrong, when he had reached the end of his facts (and remarkable facts they often were, collected by a master observer), in drawing upon his philosophy. Like a ski jumper who takes off from the ground into the air without batting an eye, Aristotle sails calmly on with his discussion, devising new "facts" from theories which were the product of his cultural background rather than of his observations.

In contrast to this—and anyone can verify it by a little reading for himself—is the attitude of Aristotle's pupil and friend, the botanist Theophrastus. This gentleman, as has been too seldom noted, had the right idea, as we see it today. Whenever he reaches the end of his own observations, he says so. Beyond that point

he may tell you what others say, and what the common belief is. But in such cases he winds up with these pregnant words, "This, however, is subject to further investigation." Theophrastus' *Enquiry into Plants* is worth reading, not only for the light it sheds on Aristotle's failure, which is in a sense that of us all, but because it gives a vivid glimpse of what the Greek of the third century B.C. saw and knew about one very important phase of his environment—the vegetation.[3]

Insofar as it was not quite overshadowed by that of Plato, Aristotle's way became and remained the fashion. Here and there the businesslike Romans gave indication that the tidiness of a scientific viewpoint had its appeal. Cato and others after him evidently preserved all they could of the agricultural lore of the Carthaginians.[4] That was practical. So were medicine and structural engineering, and something was done about both. Not much, however. The main thing these old realists did was to keep on hand what others had found out. It never seemed to cross their minds that more and more—without limit—could be found out and that the finding would give marvelous control over materials and energy. Or if it did, perhaps they realized that the old problems of man's relation to man would still be left to solve—problems bad enough in a

[3] Theophrastus. *Enquiry into Plants*. Translated by Sir Arthur Hort. Vol. 1 and 2, Loeb Classical Library, Putnam and Sons, New York, 1916. Cf. also Greene, Edw. L. *Landmarks of Botanical History*. Misc. Coll. Smithsonian Institution, Washington, D. C., 1909.

[4] Cato. *De Re Rustica*. Translated into English by William Davis Hooper. Loeb Classical Library, Harvard University Press, 1934.

world uncomplicated by new knowledge. At any rate, while we can thank the Roman poet Lucretius for a glimpse of a wonderful world of ordered scientific law, the effect of his poem, *On the Nature of Things*,[5] in stirring people up to investigate nature was practically nil. It encountered the inertia of a powerful culture form.

SLOW DEVELOPMENT OF SCIENCE

One of the most interesting problems in the development of man's knowledge of his environment lies in the frequent long periods of arrested growth which followed the accumulation of a respectable body of fairly accurate knowledge. This cannot be wholly explained by saying that these lapses were due to lack of social need. Medical improvement and mechanical devices would have served medieval China just as they did nineteenth-century England. And in food production, the limits of empirical knowledge have long been strained to the bursting point in China as in India, while malnutrition was evidently widespread in Europe of the Middle Ages.

A common explanation of these lapses has been that until scientific method was invented no orderly progress was possible. But we have seen that Theophrastus understood this method and explicitly described it. Archimedes and doubtless many another understood

[5] Lucretius. *De Rerum Natura*. Translated into English by R. C. Trevelyan. Cambridge University Press, 1937.

enough of it to have developed the rest in time. Why did it not prevail? The answer is not in human capacity or need; it can only be in terms of the community culture. Culture largely controls the standards and forms of human activity. It even sets those of the scientist—the scientist, who imagines himself the most independent of men.

And so, before the culture of Western Europe was ready to furnish the forms for scientific advance, a long period of incubation was necessary. That is really something to think about—fifteen centuries passed before men were ready once more, as in the days of the Greeks, to look about them with seeing eyes!

The story of this change is long and most involved, and each one has to read it for himself. Certain features, however, are clear enough. There was a welding of Jewish and Christian ideas of heavenly order with the Roman passion for earthly order. This took form in the Church of Western Europe, which spread and prevailed until the idea of order and law was ingrained throughout the culture. Once that was accomplished, the stage was set to start the scientific method working. Doubtless the geography brought back by the Crusaders, no less than the re-established connection with the Greek mind, played its part. So did the wealth and leisure due to awakening commerce, and later the clear formulation of the inductive scientific method by Sir Francis Bacon. But these influences would have been fruitless in a culture not properly

conditioned[6]—in this instance by the idea of a Divine Order controlling the universe.

And so men set to work to learn the order which God had decreed among His works, feeling that some of the rules of the game were to be had for the effort and that this ought to be a very useful kind of information to have. Feudalism, breaking to pieces, was being replaced by capitalism which could, quite conveniently, use this kind of knowledge. As a result, the progress of knowledge was a curious mixture of the kinds most urgently needed for the world's business, and of the kinds which could be obtained with existing technique and symbolism.

In looking back over the history of science since it began in earnest in the sixteenth century, there is not much that is not grist for our mill. All of the natural sciences, and the social sciences as well, deal with factors in our environment. The first knowledge to be reduced to order was that of the heavenly bodies, so distant that we can perceive only their regularity and the most general facts about them. When it became known that the earth was one of them, and a spheroid, that was a great step toward understanding it scientifically as our place of abode. Some perspective became possible through laborious and precise records of the movements of sun, moon, stars, and planets; and through subsequent calculations a picture of their

[6] Nordenskiöld, Erik. *History of Biology*, Part I, Chap. 12, pp. 87–89. Alfred A. Knopf, New York, 1928.

relation was worked out. Needless to say, this information was of prime value in traveling about on this particular planet and exploring it, and therefore was culturally effective.

Then came study of the forces which hold this universe together and by which work on earth is accomplished. It was a great thing to discover that these forces are universal and impersonal. A king will drop just as a stone or a dog, should he fall from a tower. As these forces came to be understood, they were put to work in a world in which labor, largely because of the Great Plague, had suddenly become expensive and scarce, while the money to buy, in the form of gold from the New World, had rapidly become abundant. Clocks, other machines, and engines were developed and found ready use.

Presently, through these studies, it became possible to manipulate and weigh matter with accuracy—even the invisible gases. And unexpectedly the study of these same elusive and mysterious gases gave the clue to chemical change and constitution. The same experiments which revealed oxygen showed the part it played in the activities of plant and animal life. Shortly the fixation of carbon from the air by plants to make organic compounds was cleared up. The chemical bond between the living and the inanimate was established. The physical environment could no longer be thought of as something incidental and apart from the living organism. The two were essentially and intimately re-

lated on the plane of physics and chemistry. This was at the beginning of the nineteenth century, and shortly thereafter the synthesis of urea from inorganic salts in the laboratory[7] clinched the matter. Thus opened the hope of understanding the chemical reactions of living organisms well enough to control them for our use.

VARIOUS APPROACHES TO ECOLOGICAL STUDY

Meanwhile the puzzle of life and environment had been approached from other very different angles. One had to do with the study of population, the other with the geography of life, particularly plant life.

During the eighteenth century a number of influences, for example, the cultivation of potatoes and the development of factories with the resultant exchange of commodities for food, quite changed the subsistence balance in Europe, calling attention to the question of population growth, food production, etc. This led to a comparison of the reproductive rate with the rate of survival and a study of the means by which populations keep in balance with the means of subsistence. The upshot was a clear statement that large numbers of individuals are eliminated by such agencies as war, pestilence, and famine.

This idea was subsequently applied by Darwin and Wallace to organisms in nature.[8] Coupled with the idea that organisms are constantly varying and that

[7] Furnas, C. C. *The Storehouse of Civilization.* In press.

[8] Nordenskiöld, Erik. *History of Biology*, Part III, Chap. 12, pp. 485–488. Alfred A. Knopf, New York, 1928.

some are fitter than others to survive in competition, it gave rise to the Theory of Organic Evolution by Natural Selection. According to this theory, environment was held to play an essential part in selection, and so in shaping the course of evolution. In this manner, a second scientific link was forged between life and environment, the first perhaps being the demonstration of nutritive chemical relationships already mentioned.

Carrying this problem of populations and survival down to the present, it has been found (*a*) that environment may act to release or stimulate inherited variations and to produce mutations; and (*b*) that as populations approach the limits of subsistence, starvation may not be so marked a factor in group survival as decrease in reproductive vigor. Meanwhile, of course, statistics have been developed as a powerful technique in analyzing population trends. Likewise there have arisen experimental methods of studying population changes in lower organisms, not to forget the modern science of genetics.

Retracing our steps to the beginning of the nineteenth century, we find that the vigorous explorations of three hundred years had produced results. Linnaeus had already made general a means of naming and classifying living organisms.[9] Many kinds of plants and animals from distant regions had proved valuable in

[9] Nordenskiöld, Erik. *History of Biology*, Part II, Chap. 7, pp. 209–214. Alfred A. Knopf, New York, 1928. Linnaeus, C. *Species plantarum*, 1753.

European commerce. Thus the work of the naturalist became useful, and so, respectable.

For example, the great port of Liverpool receives tribute in the form of cargoes from the Seven Seas. Spices, drugs, dyestuffs, precious woods, fibers, and foods—the list has no end. It becomes a matter of the most acute practical importance to be certain of the source and point of origin of much of this material. At any rate, the services of those who know the plant life of the earth are in frequent demand by those who handle its commerce at the port.

Again, the late Professor John M. Coulter, who served during the Great War of 1914–18 as botanical counselor to the U. S. National Research Council, found that, of all the information he *might* have given, the kind most in demand was of the sort just mentioned. During that tragic emergency the Council often found itself concerned with questions of identity, source, and supply of materials. Thus, this problem of the diversity and pattern of life is not wholly an idle pursuit. And so we may ask how it came about and what meaning lies behind it?

Previous to 1800 there was little better to offer on this question than the Doctrine of Special Creation. Despite the fact that this was a theological conception, it must not be forgotten that nothing better could be advanced at the time, on the basis of actual knowledge, to fit such facts as were available. It represents an important step in scientific formulation. Briefly, this doc-

trine held that organisms were as they were, and where they were, because they had been made so. It had the beauty of being, at least, simple and explicit.

But now began a systematic exploration, as well as an examination of scattered facts from many places. Von Humboldt saw much of the earth and tried to develop a rational account of its surface features.[10] Geology and the study of fossil life were developed with the gradual adoption of the idea that the past could be explained in terms of the processes which go on today. In turn the knowledge so obtained could be used to explain the present. This is really much like reasoning in a circle, as the acute scholastic enemies of the new science quickly saw; but to their discomfiture, it has worked, and so been justified.

We must not forget that as an army marches on its belly, so science advances by its technique. And as the provisioning of an army is affected by the country it traverses, so the particular technique which science must use in a given case is not to be determined beforehand in the lucid calm of the study, but rather, as science moves along, in contact with the particular problems in hand. Very often, to describe the origin of a particular technique we have no better term than "intuitive"—"artistic," if you prefer.[11] What is required is that it must work when applied in the lab-

[10] Humboldt, F. H. A. von. *Cosmos*. Translated into English by E. C. Otte. Harper and Brothers, New York, 1866.

[11] See Birkhoff, G. D. "Intuition, Reason, and Faith in Science," *Science*, Vol. 88, No. 2296, pp. 601–609, 1938.

oratory or field. And in the study of earth, the assumption of "uniformity" certainly has given such a technique.

PROGRESS DURING THE NINETEENTH CENTURY

By the end of the nineteenth century two very important truths had emerged from geographical studies, aided powerfully by the Evolution Doctrine.

(*a*) The great *types of vegetation* with their associated animal life have their basis in climate and other environmental factors. The tropical rain forest, for example, occurs wherever there is sufficient moisture and suitably high temperature. Grassland is the expression of moisture inadequate for forest but sufficient to prevent desert.

(*b*) The distribution of the *species* of plants and animals is to be explained in terms of the evolution of life on a changing earth. As life has been gradually developing, the outlines of seas and lands have slowly shifted, too, creating or removing barriers. Thus groups of species have been isolated or joined and thrown into competition. Thus it happens that while the great climatic communities have their structure or character (i.e., forest, grass, desert) largely determined by the present environment, their composition (the species in them) must be understood chiefly in terms of past events.

In the past, so far as any practical stimulus to a study of natural conditions is concerned, we must look

mainly to forestry and fishing. Applications to grazing, which are exceedingly vital, have come quite recently, while agriculture has been approached either confusedly or from the standpoint of its speedy industrialization rather than from its position as a factor in the landscape, so to speak. In this country the recent practical emergency created by soil erosion, forest and range depletion, and agricultural maladjustment has been a powerful stimulus, of course, toward a broader attitude.

The foresters of the nineteenth century were responsible for studies on competition among growing trees, light relations, and the like; but it is unquestionably true that the beginnings of a modern science of environment and life are due largely to the scientific enterprise of isolated naturalists, especially botanists.

Scandinavia is a pretty thoroughly studied region from any point of view. Its plants, animals, and geology are well known. The topography is youthful, exhibiting a large variety of well-marked habitats in small space. It is not surprising, then, that the smaller communities characteristic of dunes, marshes, and boulder fields, for example, should come to be studied there. They were, in fact, studied as to both character and origin by the Danish botanist Warming.[12] While recognizing the broad effects of climate upon plant life, he pointed out the importance of local, or topo-

[12] Warming, Eugene, *Plant Oecology.* Oxford University Press, 1925. First edition (Danish), 1894.

graphic, conditions. Also he showed that not only do communities have a life history, but that there is a sequence of development from one type of vegetation or plant community to another. This he designated as (plant) succession. His book, published first in Danish in 1894, in German later, and in English in 1909, had an immediate and powerful effect, which still prevails. For the first time it became possible to examine the varied landscape, not as an unrelated mosaic, but in terms of developing communities with more or less parallel tendencies. Further light was shortly available from the new knowledge of topographic change, or physiography, and from studies in plant physiology which helped explain the mechanisms which enabled certain plants to fit given environments.

THE WIDENING RANGE OF ECOLOGY

It was not long before this new framework established by the plant ecologist proved its utility to the student of animal life. Animals are dependent upon plants, and their grouping shows it. Presently it became quite apparent that the animals, instead of being incidental, are truly a part of the community in nature. The term *bio-ecology* was coined to cover the environmental relations of both realms of life, although the one word *ecology* should suffice.[13]

[13] Cf. also the use of the term "Plant Sociology." *Vide* Braun-Blanquet, *Plant Sociology*, translated by Fuller and Conard. McGraw-Hill Book Co., New York, 1932.

This broader point of view has been encouraged by a better understanding of the soil. Soil is now known to represent a prolonged process of development in which the activities of living organisms collaborate with inanimate materials and processes. The living community extends below ground, too; and the activities, not only of roots and of animals, but of microorganisms, are essential factors there. Thus the whole trend has been to emphasize the unity of the natural world, or at any rate, its closely woven interrelationships.

THE PROCEDURES OF SCIENCE

We shall see later, in somewhat more detail, how these advances in our knowledge have been possible. But until then, let us remember that for the most part they have been the result of persistent and repeated examination. Ask any group of fifty or a hundred people to explain just what happens when the grass becomes green in the spring. Give them a day to find the answer. Two things will surprise you: the number who have ready answers; the small number who obtain these answers by getting down on hands and knees and really seeing what happens. Actually such verification is often an easier matter than framing an intelligent question in the first place; but the importance of this direct, sensible way of getting an answer is not as yet a part of our cultural make-up. Or as we say, "We never thought of looking to find out." Neither

did Aristotle, always, and Plato was not even interested in the possibility!

Science has much important work to do for mankind both in education and in other affairs. But none is more important than to take the public completely into its confidence on the method by which it goes to work. Now that much of our science has become exceedingly technical and dependent upon elaborate instruments, we are likely to forget that instruments are, after all, merely a more sensitive and effective means of looking, or hearing, or feeling. And, of course, such observing must be guarded and guided by intelligence—so much goes without saying. For all of that, science is a process of finding out what is going on, in terms of our five senses; and the symbols of science are a means of recording this. Given the right sort of symbols, we can often work out new relationships with their help; indeed, symbols may be powerful tools. Yet even so, the results are no good until we have come back to nature once more and looked (or felt, or tasted, or listened, or smelled) to see if they can be verified by experience.

It would be wrong if this emphasis on observation should obscure the vital importance in science of symbols for objects and relationships. The symbols used in speech and writing are, after all, the instruments of culture and the means by which knowledge is preserved, clarified, and communicated. They are of value only as they are precise and used with precision. Not

all languages are equally suitable for this process even when they have been tempered by long use; and certainly those that have not been so tempered are limited in their value. Thus, command of a suitable language is an essential part of the training of a scientist. This goes far deeper than a ready possession of technical terms or the facility with which language may be used to establish plausible beliefs. It involves an understanding of the way in which meanings are arrived at and expressed through the use of words.

MAN IS A PART OF THE NATURAL ENVIRONMENT

To resume, after this really necessary digression, there remains one more phase of our story. Without saying so, we have, up to this point, looked on man as someone more or less outside the picture. He examines nature and tries to understand it, as one might witness a passing show. But in all truth the story is not so simple. Man is not only a watcher; he is a member of the cast—a part of nature, himself. Many of his spokesmen, certainly the more vocal of them, have fought stubbornly against this idea. They do still, in spite of the overwhelming weight of evidence which they ostentatiously ignore.

Experience shows that it is always hard to secure a proper perspective on events in which one is caught as an actor. But the science of man has, by persistent effort, made long strides toward working that miracle. Evolution, based on comparative anatomy and

increasing numbers of fossil remnants, has made clear enough the animal origin of man. Biochemistry and other branches of modern physiology certainly confirm the essentially animal character of his physical behavior. Psychology has established that there is much in common between the mental processes of man and those of his lower kindred, despite the human attributes which make possible a new and higher level of achievement.

Man's environment includes not only the world of nature outside man but the world of human society as well. We have already talked about the growth of knowledge concerning the former. It is proper to add, however, that much of value has been contributed by the so-called "human geography," even while students in that field have continued to debate the question, "What is geography?" Using the data of physical geography, the human geographers have developed many significant relationships between environment and human activity.[14] In no small measure such studies have helped illuminate our knowledge of history. Geographers have also studied the changes in population and industry in rapidly developing American communities,[15] and thus have made substantial contributions to the social sciences.

[14] Thus C. L. White and G. T. Renner (D. Appleton-Century, New York, 1936) have designated their book *Geography, An Introduction to Human Ecology.*

[15] E.g., Frost, R. B. "Lorain, Ohio: A Study of Urban Geography." *Ohio Journal of Science*, Vol. 35, No. 3, pp. 140–238. 1935. Cf. Also reference on page 167 of this book.

The human environment itself, that is, the society of man, has proved to be at once absorbing and difficult to study. The scientific ideal of impersonal truth-seeking is here all but impossible, quite apart from the extreme technical difficulties which arise from the very nature of so complicated a subject. As in other less intricate fields of truth, the attack has gone on piecemeal, with workers on the various fronts often out of touch with one another. Until recently human sociology has been too much divorced from anthropology, and economics from both. So far as is known, no book which dealt with the general problem of human ecology appeared until about 1935.[16]

Without disparagement of the great amount of very important work done elsewhere, the advances made in anthropology seem to afford the most important basis for understanding the character of the human environment of man.[17] Through the study of primitive society, supplemented by archaeological findings and attention to human physical development under various conditions, the anthropologist shows that the influence of the human environment is expressed in what are known as *culture patterns*, or culture forms.

Naturally the culture pattern is most definite and stabilized in simple, well-adjusted communities, and tremendously complicated by individual and group behavior patterns in more advanced cultures. In the

[16] Bews, J. W. *Human Ecology.* Oxford University Press, 1935.
[17] For references, see page 166 of this work.

modern civilized world the rush of technologic change has produced widespread disintegration and confusion of older patterns at a time when mankind faces the task of a conscious, deliberate adjustment of its own cultural destiny.

Such then, in brief, has been the progress of our scientific knowledge of life and environment. Through the facts developed in this chapter we have a means of analyzing the forces which shape the individual directly, which intervene between the external world and the individual, and through which he in turn acts upon his general environment. It is possible, in such short compass, to indicate only the more striking and significant steps. Many that are very important have, perforce, escaped mention.

Enough has been said to show that life and environment are thoroughly interwoven, and that any point of view which ignores this fact (except as a convenience, for purposes of analysis) does not comprehend the world in which we live.

It is now our task, on succeeding pages, to discuss certain very general principles which have emerged from the studies we have reviewed. The bearing which these principles may have on the business of living will be developed and elaborated in terms of the scientific knowledge upon which they rest.

CHAPTER III

The Main Divisions of Environment

For Purposes of Analysis the Physical Environment Is Resolved into Lithosphere (Rock), Hydrosphere (Water), and Atmosphere (Air). Living Things Are Often Considered as Constituting the Biosphere. These Four Systems Interpenetrate

---

FACTORS IN THE ENVIRONMENTAL COMPLEX

THE environmental relationship (including that of the individual to the community) is as much an attribute of the living organism as respiration or reproduction. There can be no true natural history which omits the consideration of it, except as such omission is a provisional device, deliberately employed to simplify a given laboratory problem. Such a case would be like giving an animal anesthetic so that motion and conscious sensation should not complicate an experiment upon his circulation; we would not pretend to ourselves that the behavior of the drugged animal was typical, or complete, or normal. And yet we would have to admit that much can be learned from him which is useful in understanding the animal completely alive and active. When we thus deliberately simplify and control a situation in order to make scien-

tific observations we are employing the method of experiment. This very necessary procedure in science is largely used in the process of analysis, whereby we attempt to understand a whole by first studying the various factors which make it up. Needless to say, we must ever be on guard in using such knowledge. The whole is not the sum of its parts, but a relationship among them.

Just as, in such an analysis or dissection, we can separate out constituent parts of a problem, so we can recognize four great sets of factors in the complex of environment and life. Only in a very trivial way can we separate them as a matter of physical procedure; what we do is to consider them in turn, separately. It is a matter of attention rather than of isolation. We can get a bit of the atmosphere into a container, away from its normal influences. We can remove the water from a plant if we kill it—and incidentally have less than 15 per cent of the plant left afterward. These operations, of course, have their place, and it is an important place; but the trouble they impose merely serves to remind us that actually, in nature, the entities are all inseparably related. The very character of the terms used to designate them separately reveals itself, on scrutiny, as merely a clever and useful working with words to establish identities which are in fact not absolute. Observe—

Lithosphere—the world (literally, the sphere) of rocks
Hydrosphere—the world of water

Atmosphere—the world of air
Biosphere—the world of life

True, each is studied by its special division of science, but only as a matter of attention, not in any sense of actual separation. Imagine the geologist who ignored water, air, and fossil organisms in his study of the rocks!

In the chapters to follow we shall have rather more to say about the biosphere than about the other topics just listed. For the present we shall turn our attention to the rest, often grouped as the physical environment.

THE LITHOSPHERE

The solid portion of the earth is, of course, the framework of the physical environment. In its depressions are the liquid portions of the hydrosphere, where aquatic life is found. Its solid surface affords the footing for land organisms. Its contours determine the nature and impact of climate. And its substance provides the mineral salts essential to all living organisms.

The position of the lithosphere in space and its size are matters of no little importance. If it were too near the sun, or too remote from it, the temperature would be unfavorable to life in any form we can conceive or calculate. For one thing, water in the liquid state would not exist—and plants and animals consist largely of liquid water. If the lithosphere were much smaller, it would not be able to hold an atmosphere by gravitational attraction; thus gaseous exchange, so

essential to life, would be impossible. On the other hand, a planet much larger than the earth, as is the case with Jupiter, would possess an atmosphere so dense as to exclude the necessary solar radiation from its surface—again making impossible such an energy system as life.[1]

The spherical form of the earth and its motion with respect to the sun provide the astronomical basis of climate, while the pattern of land and water modifies the detailed expression of climate.

The surface of the lithosphere is a scene of constant change due to the impact of climatic forces and the dynamics of internal adjustment. Geologic history is largely a series of cycles involving erosion, deposit, and uplift, which alter the pattern of land and water and the contours both submerged and dry.

These changes redispose mineral materials, modify climatic patterns, and create or remove barriers to life; thus they profoundly affect the course of life and the communities into which it falls. While the orderly progress of erosion leads toward a mature and level topography known as the peneplain, such a condition is not commonly met with. Apparently the immense mass of material which is removed and carried to sea during this process creates conditions of unstable equilibrium, followed by changes in continental outline and elevation and a renewed cycle of erosion.

[1] Henderson, Lawrence J. *The Fitness of the Environment.* Macmillan Co., New York, 1913.

As the lithosphere supplies the framework of the environment, so its surface material constitutes the matrix of the soil, the mineral basis of which is weathered rock. Many important physical properties of the soil depend upon the size of these rock particles, ranging from gravel, through sand and silt, to clay. This material is also largely the source of the mineral nutrients within the soil. But soil arises from the fact that this weathered rock is lived in and upon. Soil includes not only the rock particles but water, gases, organic remains, and organisms. It is a system exhibiting organization, and undergoing a process of development.

Both the chemical and the physical properties of the original rock material are profoundly modified by this process of development, whose degree is reflected in the structure of the soil profile. (See page 90.) A mature soil is marked by a high energy content, great organic activity, and a maximum capacity to support life under the given conditions. It also reflects in its structure the climatic conditions under which it has developed. As soil formation proceeds, so does the stabilization of the living community involved. Anything which disorganizes the mature soil profile or reverses the process of its formation interferes with its capacity to sustain life. This may happen as a result of normal topographic change. Or the rate of such change may be enormously accelerated by climatic changes which destroy the protective vegetation.

Again, such acceleration may result from biotic interference, that is, interference by living organisms, notably man.

Human activity has most seriously interfered with the delicate balance which involves soil, living organisms, and climate. Man's flocks and herds have often been permitted to graze too closely, removing much of the protective mat whereby grasses and herbs protect the soil against erosion. With even greater finality, the ax, fire, and the plow have removed the natural covering over much of the earth. Thus have been destroyed the communities which have for ages contributed toward the building and protection of the soil, the absorption of water, and the adjustment of life to climate.

Following the plow, various types of land use and management have been developed, frequently with little reference to the preservation of the soil, let alone its improvement. The resultant arrest of soil development, and even the removal of the soil by erosion have often been overlooked until, in many cases, the land has become unworkable or even uninhabitable.

Those who, having some knowledge of geologic processes, insist that erosion is natural and inevitable, should be reminded that man has enormously accelerated it. True, human activity does not cause erosion. But such activity as we have described permits it to speed up, without restraint from those checks which

generally allow soil to form faster than erosion removes it.

Abundant illustrations of this effect are to be seen on every continent. In this country the hillsides of Connecticut, the piedmont area of the South Atlantic region, and the wind-eroded area of the high plains are stark examples. Lesser damage, with an average destruction of 30 per cent of the original soil, is to be found throughout the country as a whole. One can find hillsides gullied even in the matchlessly handled farm region of eastern Pennsylvania.

One of the subtler effects of soil exploitation is the depletion of certain of the minerals so necessary to plant and animal nutrition. A youthful soil will have about the composition of its parent rock—not always completely suited to the requirements of living things. But as time goes on, the lack is usually made up in one way or another, as by the contributions of animals which wander there. This leaves certain elements not always sufficiently abundant, even in the mature soil. When lost, they must be supplied—often a costly and inconvenient procedure—or plants and animals, including man, will be improperly nourished.

With respect to the lithosphere, then, we may say that whatever retards the rate of destructive change and holds land forms stable while encouraging the constructive processes of the soil, makes for the greater effectiveness of life as an agency of orderly transformation. In general, this works to the advan-

tage of man, and he should know it. On the other hand, whatever works counter to these ends is very likely in turn to work counter to the permanent welfare of mankind. The challenge that comes from these considerations to intelligent and thorough human control seems clear enough.

THE HYDROSPHERE

The hydrosphere is the water portion of the physical environment. In the seas, lakes, and ponds it affords the habitat for aquatic life. This kind of life exhibits its own delicate balance and organization into communities. This balance may be upset by many causes, and particularly by human interference through pollution and otherwise. At the same time the human race is heavily dependent upon these aquatic sources for its own proper nutrition. These statements are all true of the rivers of the earth as well. In addition, however, the rivers are active agencies of erosion and transport, producing environmental changes important to life.

Water is an essential constituent of the soil, of living organisms, and generally as vapor, of the atmosphere. The dynamics of life are largely those of heterogeneous materials in a watery medium. Water is the basis of the soil solution. It is a means of energy transfer and an agency in maintaining growth and form. It is also a raw material in food manufacture and a means of material transport within the living

body. It has unique, intrinsic, essential properties in the habitat and in the organism. Its presence on earth is a part of earth's theoretical fitness for such a system as life.[2] In brief, our understanding of the relationships into which water can enter is amazingly parallel to our understanding of the processes of life.

The generalized behavior of water in the environment is represented by the hydrologic cycle, or better perhaps, simply the water cycle. This is the process by which water, moving into unsaturated air as vapor, is transported and later condensed to fall upon the earth, and includes its movements on and within the earth until the cycle is repeated. The energy for this process is furnished by the sun. Part of the cycle is atmospheric, part lithospheric, and part purely hydrospheric.

The moisture falling upon the lithosphere either runs off, soaks in, or re-evaporates. That which runs off does the work of erosion, fills the streams, and organizes the drainage patterns, eventually reaching the seas. Except as it may form aquatic habitats or be incidentally caught and utilized en route by plants and animals, the main significance of run-off water for life is in shaping the terrestrial environment.

That which soaks in, however, not only takes part in soil formation and recruits the underground water reserves but is utilized by plants in the formation of

[2] Henderson, Lawrence J. *The Fitness of the Environment.* Macmillan Co., New York, 1913.

foodstuffs and the composition of their bodies. It may subsequently be used by animals and whole series of lower organisms, both plant and animal. In the end, however, reorganized as water, it returns to participate in the endless cycle from which it was caught and temporarily retained to serve the functions of the living. The amount of water so utilized is a fair measure of the abundance and effectiveness of life, since water, directly and indirectly, forms such a high proportion of living organisms and is so indispensable to them.

It should be clear that the water cycle places water at the disposal of land life during the phase between precipitation and final arrival in the seas or lakes. The welfare of land communities is served best by effective absorption and orderly drainage. This supplies the maximum of ground-water needed directly by living things and restrains the destruction which is caused by unregulated run-off on the one hand, or inadequate drainage and consequent flooding on the other. Thus the maintenance of a properly balanced water cycle is of the highest practical importance. Any influence which tends to prolong the useful phase of the hydrologic cycle and conserve water for the use of living organisms works in general for a better organized and more effective development of life, and so toward the benefit of mankind; anything which operates to disrupt the useful phase of the water cycle is biologically and, as a rule, socially destructive.

THE ATMOSPHERE AND CLIMATES

The atmosphere differs from the two great environmental entities just discussed in one important respect; it is almost wholly beyond our control, and thus demands a different approach. True, we may air-condition our homes, grow plants and animals in shelters of various kinds, utilize trees for windbreaks, etc. Life is not always obliged to receive the impact of atmospheric forces uncushioned. Conditions within the forest, for example, are very different from what they would be without the protection afforded by the dominant trees.

We should study the great sweep of change in lithosphere and hydrosphere with the hope of encouraging those processes which benefit us, of retarding those which work against us. But with the great course of climatic change, our greatest immediate hope lies in understanding so that we may adjust our affairs to the more or less inevitable. At least, if we did so, the benefits would be great and immediate. A national economy based on the false assumption that the most favorable years are the true norm is plainly out of balance.

The great pattern of solar radiation underlies the activities of the atmosphere. This pattern is quite regular geometrically, but atmospheric behavior is in part due to the fact that the earth's surface upon which the radiation falls is not uniform. The pattern

of land and water is extremely irregular. Moreover, the character of the radiation itself varies from time to time with the degree of sunspot activity. Evidently, from geologic history, there have been prolonged periods when the effectiveness of radiation, whatever the cause, was very different from what it is today. The general course of geologic climate is believed to be milder than that of today, while there is ample evidence of periods much more severe.

Besides furnishing the energy which life utilizes, the sun's radiation produces heat; and this heat in turn produces action within the fluids of the earth—movements of water within the hydrosphere and movements of air within the atmosphere. Light, warm fluid tends to be displaced upward by the greater pull of gravity on denser, cold fluid which tends to sink. These changes produce lateral displacements as well—the familiar winds and ocean currents. This activity is profoundly affected by the fact that land heats and cools more rapidly than water—the latter being said to have greater specific heat. Thus changes in temperature are more rapid and extreme in continental interiors than upon the coast and at sea. In fact, we recognize two great types of climate—the continental and the oceanic. The former, in addition to its more violent temperature changes, is characterized by high rates of evaporation, scant rainfall, and consequently less available moisture.

The activity of the atmosphere is also modified by

the rotation of the earth, most noticeably in the prevalent direction of planetary winds, and the great cyclonic course of ascending and descending currents, or low-and-high pressure areas.

The conventional weather map shows the areas of low and of high pressure, the course of wind movement, and the pattern of sunshine and of precipitation. It represents the pressures and movements of the atmosphere at its base—the surface of the earth—and is therefore merely a spherical plane showing little of what is happening in the third dimension which extends vertically to the top of the atmosphere. The incompleteness of such a picture is clear if one will contrast the appearance of tobacco smoke in a room illuminated only by strong light coming through a slit with the appearance of the smoke in a normally lighted room.

With the development of aviation and balloon measurements the events of the upper atmosphere have become better understood. They have been shown to be of great importance in understanding and predicting, through the use of the "air mass" technique, the course of atmospheric events. The classification of rains into "warm front" and "cold front" types is based not solely upon the lateral contact between warm and cold air masses but upon the overriding or undercrowding of one by the other, in the upper air. If the mass of air at the earth's surface is warm, and becomes chilled from above, its moisture

will fall in sudden and localized storms. These may produce severe local erosion of the soil, but seldom extensive regional floods. Such floods arise when the lower mass of air is cold and overridden by a great mass of warm air, from which it continuously condenses moisture over a wide area, giving prolonged and general, rather than locally violent, storms. Because of its greater density, there is a tendency for the "cold front" to remain at surface level, meanwhile curving centripetally into the invaded low-pressure area. The "warm front" mass, on the other hand, being less dense, tends to be lifted and occluded by the colder air which it encounters and penetrates.

Thus we have a geometric extension of the familiar record of the weather map, which commonly shows the lows and highs passing across the continent in a northeasterly direction, with precipitation along their margins of contact. Also of the familiar statement, "Normally, highs that follow lows bring clearing weather, while lows that follow highs bring unsettled weather."

The study of the dynamics of the atmosphere, whose expression is the weather, is meteorology. The subject which deals with atmospheric phenomena statistically in order to determine the pattern in space and time is climatology. Climate has sometimes been roughly described as "the average weather"; perhaps it would be more accurately called "the characteristics of weather." At any rate, the study of climate is of

primary importance in interpreting the relation of the physical environment and life.

It is not a simple matter to study the patterns of climate in space. There is no limit to the detail into which one can go in dividing the earth into climatic provinces. The practical problem, of course, is to get some kind of map which shows the general relation of climate to natural communities of plants and animals. Neither temperature nor rainfall, taken separately or together, is enough for this purpose. It has been known for many years that evaporation must be considered, too. Forty inches of rainfall is more effective in New England, where the evaporation is slight, than in eastern Kansas, where it is high.

Recently a way has been found to calculate climatic provinces, taking account of rainfall, evaporation, and temperature.[3] Combined with the seasonal distribution of rainfall, this gives a very serviceable classification, clearly related to the natural vegetation, and to many human activities as well. Such a map is extremely valuable in studying population movements and agricultural hazards, and in planning a proper utilization of land. It must be borne in mind that such provinces are not regular in shape, and that accidents of soil and topography may greatly modify the impact of climate, particularly in marginal areas between provinces.

[3] Thornthwaite, C. W. "Climates of the Earth." *Geographical Review*, Vol. 23, No. 3, pp. 433–440, July, 1933.

Quite as important as the pattern of climate in space is its pattern in time. The calculations just referred to cannot be based upon a single year's observations, or even upon those of a decade. All weather is exceptional. During the time since weather records began in the midcontinental area there has not been a single year without some spots wetter than average, others drier —notwithstanding general conditions of drouth or the reverse. Yet there seems to be a tendency for extreme years to fall into groups, of which the devastating drouth of the 1930's is the most recent and striking example.

Considerable effort has been made to demonstrate the existence of cyclic regularity in climate, with a certain amount of success. Fluctuations of the order of magnitude of the sunspot cycles—eleven years and multiples thereof—appear to have some basis. But the safest, most practical statement to make is that fluctuation is inevitable, extreme years being as much a part of the picture as average years. The problem is to determine the extent, and if possible, the frequency of the extremes.

On a larger scale, reaching back through centuries and millenniums, there is evidence of wider climatic fluctuations, with important consequences in the migration of plants and animals, including man. Indeed, a study of these changes supplies information of the greatest interest in interpreting the communities of the present. These communities are as much a product

of the past as of conditions today, and no account is complete which ignores that fact.

Through our study of the pattern of climate in space and time we can arrive at this principle: The activities of man must adjust themselves in space and time to the realities of climate. So far as modern culture succeeds in doing this, it works to our benefit; so far as it fails, man works himself harm.

Thus, in our study of the processes of the three great components of the inanimate environment, lithosphere, hydrosphere, and atmosphere, we find that principles emerge which must be reckoned with in the planning and control of the relationship of modern society to its environment.

The biosphere will be discussed in subsequent chapters.

CHAPTER IV

Human Society as Environment

Human Society Is the Immediate Living Environment of the Individual Human Being, and Is Interwoven with the General Environment. Man, Unlike Other Organisms, Has the Capacity to Understand These Relationships, and Thus the Hope of Controlling Them

---

THE SOCIAL ENVIRONMENT AS A PROBLEM

HAVING thus examined briefly the physical environment, we move on to consider the realm of the living. We begin, however, not at the bottom, but at the top of the ladder, with man rather than with more lowly organisms. Admitting that this is the most difficult and complex part of the story, it is also the most familiar. Our understanding of other forms of life is a part of our human social experience. And, perchance, this kind of approach will enable us to see the simpler relationships in a new and useful light.

There is no more absorbing subject than human society. It is constantly with us and inevitably presents many facets for our consideration. It is complicated by the fact that we are all participants and that our experience develops in each of us certain feelings or sets of values which influence our most inti-

mate and most important judgments regarding society.

The humanist frankly accepts these feelings and uses them as his basis in interpreting society through the arts. Literature represents his cumulative verdict, using language as its medium, and thus presenting his value judgments in terms subject to rational analysis and ordered discussion. The other arts have a symbolism which cannot be conveyed in words alone, but which is none the less essential in establishing and refining values and relationships.

Although the method of the artist is not, and cannot be, scientific, because it deals with matters not open to free and general examination (i.e., the individual's feelings or value judgments, however refined or widely shared), it is, nevertheless, an essential phase of our approach to the problem of environment, because it provides the basis of action. Furthermore, it represents thus far the readiest method of approach to certain complicated situations to which the technique and symbolism of science have not been applied.

Here lies one very grave danger: that the great present *convenience* of using judgments based on feeling will discourage the extension of scientific approach to matters with which science can eventually deal. "I feel thus and so about this issue, and that ends it. I shall go ahead and devote my energy to developing the same feeling in others. I shall not wait for laggard science to pass judgment." And, of course, this method is quite satisfactory to those whose

preferences, based on narrow self-interest, would not stand up under cool scientific appraisal.

To this we can reply that the scientific method of objective study can actually, at this time, be much more widely used than is commonly supposed. And also that any kind of social action will carry straight down into problems of the physical and biological world on which science does have something to say at this present time.

Take, for example, the harassing problem of the farmer in American life today. The production of food, fiber, and other agricultural commodities is an essential utility, to be maintained under any circumstances. As a utility, it should be charged to produce those things most needed by the American people. Yet such is our faulty system of distribution and finance that the farmer is under constant pressure to produce cash crops of wheat, cotton, and tobacco, while millions of us have inadequate supplies of vegetables, fruit, meat, and dairy products. Nor is the situation made easier by the fact that the grower of these latter products often cannot find an economical market for them. These are all matters which can be viewed in the light of science. And so, to a considerable extent, can we view the related fact that farming is a way of life, and may be made a good way of life.

Ask the average city individual about the farm problem, however, and he looks at you with bewilderment, saying—"Too many farms and farmers,

yet the government spends money to save the soil. Farmers are being told not to grow so much, yet my groceries come too high to suit me. It's politics, and it doesn't make sense."

THE MANIFESTATIONS OF CULTURE

We may proceed at this point, however, to examine something of what *is* known in a scientific way regarding the mechanism of human society and its relation to the general environment.

Man differs from other animals in his capacity to manipulate, due to the possession of a grasping thumb and opposing fingers. Correlated with this is a development of the central nervous system and the power of communication by speech.

Certain aspects of physical development, notably calcification of the bones, occur slowly in man, resulting in a helpless infancy and a prolonged juvenile stage. This, apart from such other influences as may hold parents together, leads to the development of the family, organized about the mother.

During this period of maturation there are developed, through imitative action and speech, certain attitudes and forms of behavior shaped by the prevailing culture. These forms directly influence behavior. They also determine the way in which any conscious experience reaches the individual. Speech is thus a manifestation of the prevailing culture. Thus any experience of which we are aware in terms of speech is

preserved in terms of culture, deriving thereby its import. The fact that the area about a human eye becomes black when bruised is not—in itself—a cultural matter but a physiological fact. Yet, let a man appear on the street with a blackened eye, and our whole concern is in terms of its cultural significance. We ask if it means accident, preventable or otherwise, or hostilities. The meaning of the experience registers in terms of cultural relationship.

The culture form is a relationship within the general environment which shapes the attitude and behavior of the individual. It is, moreover, the means by which the individual relates himself to his environment. In terms of one culture, animal intestines with their contents are good food, cheese an abomination. In terms of another culture, cheese and the guts of fish not over three inches long are desirable, while insects are proscribed. Trees may be preserved because they shelter game, because they are sacred, or simply because they are beautiful; they may be exploited for lumber or destroyed to make way for the plow. In any case the cultural responsibility is obvious, although we say, "Farmer Jones decides to do thus and so with his trees." He comes to the decision by thinking in words which his culture provides, using patterns of thought shaped by that culture; he cuts the trees with the ax or saw which his culture shaped, and his action is effective in terms of the economics of such culture. If the thing he does happens to be quite in-

effective in terms of the economics of his cultural group, we either call him crazy or vote him a subsidy, depending again on the cultural climate.

RELATION OF THE CULTURE FORM TO GENERAL ENVIRONMENT

Having thus seen that the culture form, in a sense, intervenes between man and the natural environment, it becomes important to know how this form is related to the more general environment. In its primitive and well-stabilized aspects it often shows a remarkable "fitness," giving rise to the uncritical idea that environment determines culture.

Insofar as such a statement assumes culture to be passively plastic toward the shaping action of the general environment, it is misleading. The same problem may admit of more than one solution. Clearly the solution has to be one that will work in the given environment, e.g., navigation, tillage, hunting, etc., and sometimes the choice of means is more restricted than at other times. It is true that during the early stages of cultural history, man had fewer technical means of buffering or offsetting the immediate action of his environment. In consequence his adjustments were more immediate and direct, his culture forms more obviously related to climate, topography, and native fauna and flora than might be the case at a higher level of technologic advance.

Once established, the culture form has enormous

vitality and persistence. If, as in the case of certain simple hunting cultures like those of the Eskimo or American Indian, it does not speedily exhaust the resources about it and if population is regulated, the culture form may achieve a beautiful equilibrium. In the case of more advanced agricultural forms of culture where the fertility of the land is maintained by floods, etc., a similar cultural stability may develop, as in China and the Nile Valley. In the absence of changing conditions resulting in new problems, the very perfection of such a culture may inhibit further advance.

When new conditions and problems arise, their solution is attempted in terms of the old culture, so strong is its control. These new problems may be due to injury of the material environment by demands of the culture upon it; and such injury may be carried to surprising lengths (e.g., injury by soil exhaustion or erosion, forest destruction in Europe and North America, etc.) before the culture forms responsible will alter through invention, assuming, of course, that the culture survives, which, as among the Mayas, may not be the case.

This principle has the most direct and important bearing upon practical problems now facing the American people. The waste of our natural resources, soil, forest, grassland, fish and game, water, and minerals is often attributed to individual greed. To reason thus is to miss the point. The individual exploiter has always regarded himself as a legitimate

businessman. Sentiment toward the resources being developed or toward less efficient competitors has seemed as much out of place as squeamishness in a military officer charged with gaining an objective. To display either would be, in terms of the culture form involved, a breach of honor. As evidence of this, the exploiter has been considered by his fellows a sturdy pioneer or an empire builder, depending on the scale of his operations.

ADJUSTMENTS WITHIN THE CULTURE

We can say that the culture pattern of which this attitude is an expression is one of unrestricted private ownership, of individual initiative, or of exploitation. Such an analysis is likely to confuse the issue. Rather the pattern is one which, *in regard to natural resources*, sanctioned individual profit, and immediate social profit, too, without consideration of ultimate social cost.

The importance of ultimate social cost is not a revolutionary idea. Long ago it found expression in the legal framework of many political and economic systems, and certainly may be found in our own. Witness the laws of riparian rights, eminent domain, escheat, as well as military obligation, popular education, and public health measures.

The individual should not be permitted to find it profitable to work against the ultimate interests of society. This principle has been violated not because

it is foreign to our culture pattern but because we have not generally understood the nature and limitations of our natural resources. To remedy the situation does not mean we have to—if we could—scrap the pattern. The problem is to modify it so that resources are included among the values whose conservation is paramount. That this should include human resources we need scarcely add.

In thus broadening the basis of our culture form, we can work only with the means which it, itself, provides. If we can agree that the weighing of social cost against unrestricted individual profit is not alien to our pattern, we may ask if our culture provides the means of so adjusting itself as to take more effective account of the proper conservation and wise use of natural resources.

Since power resides in the people, there can be no question of adequate authority, if the people are informed and have the will to act. The paper pulp and dairy industries of Scandinavia are evidence that individual enterprise can be adjusted to social ends without sacrifice of the principles of democracy.

Our culture, moreover, has developed along certain lines a rather remarkable process for producing change. The medium of commercial advertising in private enterprise, and the use of the spoken and printed word in political fields, combined with motion pictures and other forms of pictorial art, are unusually potent in changing the attitudes and behavior of people. Popular

education also, in spite of the charges made against it as a means of fixing outworn attitudes, is at least equally effective in developing new ones.

Should there be any doubt about this, it is only necessary to consider the changes of the last twenty-five years in personal and social standards of hygiene, domestic use of mechanical innovations, standards of taste in personal and household utilities and decorations, and attitude toward sex.

EXTERNAL ADJUSTMENTS OF CULTURE

So much for the problem of undoing the mischief wrought by our culture in the past, and the task of making it a positive means toward better relationship in the future. Close to this lies another problem, that of adjustment to changes in the environment which are due not to society but to forces from without. This problem is less immediate but deserves attention. Certainly it has been of major importance in the past, and will be again. While most of the changes to which man must now adjust himself are the result of his own activities, he has in the past encountered climatic changes of longer or shorter duration, changes in the pattern of land and water, and doubtless many other changes due to the evolution or migration of living organisms.

In the past the continental glaciations represented a major problem of this sort to which European man, at least, had to adjust his way of living. More recently,

climatic fluctuations of a lesser order appear to have played their part, including periods of decreased rainfall in the Steppes of Asia and the interior of North America. Migration has been the usual direct consequence in the steppe cultures, which give little evidence of technologic efforts to meet the emergency. Nomads fight better than they invent.

These very migrations, pushing outward into the urbanized seacoasts, constituted for the coastal areas in China, probably in India, in Asia Minor, and in Western Europe, a change in the living environment, manifest as invasion and war. War is, of course, a conflict between culture forms, but only one aspect of such a conflict. It often stimulates invention, as in the siege of Syracuse, early invasions of China, and the late World War. But in the subsequent readjustment, the culture forms involved mingle and compete, with results so variable that any generalization becomes difficult. The conquerors of China became Chinese; those of Rome, Latin and Catholic; Mexico today remains essentially Indian in race, increasingly so in politics. On the other hand, the American Indian is Europeanized or rendered culturally ineffective in the United States and Canada. Of course, the competition of cultures and the emergence of new forms from the old may occur through the peaceful channels of commerce and education. Whenever and however such relations develop, they constitute a change in the living environment of the individual.

It might not be too much to say that in the fusion of cultures there is a tendency to preserve those traits and complexes which are already developed if these are the ones which function most effectively under the particular conditions existing at the time. But this tendency involves far more than fitness in relation to the physical environment. Prestige, expediency, and other factors are often quite as forceful in determining the issue.

And so, as human cultures are modified with the course of history, they tend to retain forms which had their origin in contact with natural environments at an earlier time and often elsewhere. Thus the sensitive and intimate relationship to the natural world so characteristic of primitive, indigenous culture is lost or obscured. Sometimes the result is disastrous; at other times the maladjustment gives rise to invention and change, and so to an outcome favorable to the persistence of the social group.

SCIENCE AS AN INSTRUMENT OF CULTURE

Most significant for us is the course of events in Western Europe since the fifteenth century, a profound cultural change which can be designated as the invention and development of the scientific method and the application of its results to technology. We have already noted some of the aspects of this revolution. It is advisable to read not merely the older chronological histories of science but some of the

newer interpretations by Mayer, Hogben,[1] and others, which make clear the intimately practical relation between science and modern culture forms. The conventional science history fails signally to make clear this relationship. For an illuminating view of social consequences and possibilities, the reader is referred to the works of Veblen, and Wells, and for a very different angle to statements by Kettering.[2]

The common statement that science is an independent, impersonal way of looking at the world creates a false impression. It is not aloof and detached from the culture form; on the contrary, it is one of the most highly conditioned activities of the human being. "The sturdy scientist, hewing to the line, regardless of consequences . . . cannot even think without employing symbols, terms, and relationships which have been standardized, registered, and officially approved by competent authority. Compared to the calculated and deliberate intent—the consciously cultural intent—with which science has been fostered, the growth of poetry and business have been spontaneous wildings in human society."[3] Thus science has its inception in cultural need and grows by the use of cultural pro-

[1] Mayer, Joseph. *Seven Seals of Science.* The Century Co., New York, 1927. Hogben, Lancelot. *Science for the Citizen.* Alfred A. Knopf, New York, 1938.

[2] Veblen, T. *Theory of the Leisure Class.* Vanguard Press, New York, 1926. Wells, H. G. *Experiment in Autobiography.* Macmillan Co., New York, 1936. Kettering, C. F. "Ten Paths to Fame and Fortune." *American Mercury,* Vol. 124, pp. 14–15, December, 1937.

[3] Sears, P. B. *This Is Our World,* p. 246. University of Oklahoma Press, Norman, 1937.

cedure. But even more striking is the fact that science has destroyed the old culture forms by giving mankind an unprecedented power over environment. Ideally this should work to the benefit of all, and certainly many have enjoyed its benefits, within the framework of an industrial world where science and nearly everything else is largely subservient to a doctrine of individual profit. Practically, however, the benefits of science have worked very unequally, for the application of technology has hastened the exploitation of natural resources, producing maladjustment between society and nature to add to the disruption within society.

The application of science has been the chief agent of transformation in the past three centuries, and particularly in the past one hundred years. The annihilation of distance in travel and communication, the methods of large-scale automatic production, generation, and transmission of power, to say nothing of chemical and structural engineering, have revolutionized living.

It is now possible to produce more goods with less labor than ever before; but want, hunger, and idleness are still with us, because the technique of social adjustment has failed to keep pace with manufacturing technology. There exists little or no practical check on the use of science for destructive purposes—in fact the expenditure for war preparation exceeds that for other research rather generally. And authoritarian

government, ruling by arbitrary restriction, is spreading over the earth at the expense of democracy. Recourse to organized arms, if and when it comes, will represent merely a phase, however serious, of a cultural conflict already in progress between democracy and authority.

THE HUMAN COMMUNITY AS A SPECIAL CASE

Now the unique fact about the human community is not the fact that it is a community, nor even that it exhibits social forms. We shall see that all organisms tend to form communities, and that among certain vertebrate animals behavior patterns are largely acquired by experience of the growing young rather than being completely innate or instinctive. This is true of homing among pigeons, mode of feeding among certain birds and mammals, and many aspects, at least, of mating behavior. There is in fact a growing burden of proof upon those who speak of instinctive behavior instead of using the more cautious term, *innate factors in behavior*, in reference to vertebrate animals.

Nor is the human community wholly unique in other respects. Physiologically it must establish itself within the chemical energy-and-material cycles necessary to the continuous survival of any group of living organisms. It must have food available in the form of carbon compounds synthesized within green plants by the aid of sunlight, whether or not they are later

reworked by living animals. These foods must meet rather definite requirements as to quality, including, among other things, an adequate and proper mineral content.

Since these minerals derive from the soil (to follow up but one aspect of the problem), the nutrient cycle of which man is part must be so arranged that the soils are not ultimately robbed of their minerals. If loss occurs, then the necessary minerals cease to be available for human use. It is interesting to know that there are widespread mineral deficiencies in human diet at the present time, manifesting themselves in defective glandular function and skeletal development, or other types of abnormality. Soil depletion has caused the shifting of populations on many continents. In Greece, and later in Rome, the nutrient chain was distorted by mismanagement of lands near at hand and by increased dependence upon remote sources. Incidentally, the pressure of Rome for wine, oil, and flour from Northern Africa was a strong factor in converting that once fertile region into the goat-desert which it is today. There is, in short, ample evidence that human cultures have got themselves into bad adjustment with the environment rather frequently, as can be seen by consulting a number of appropriate sources, including numerous government reports as well as many articles in current periodicals.[4]

[4] Spinden, Herbert J. "Waters Flow, Winds Blow, Civilizations Die." *The North American Review*, Autumn Issue, 1937.

MAN'S UNIQUE POWER OF MANIPULATION

But while the human community is not exempt from the compulsions which have been named, it is unique in the fact that it has a means of describing and analyzing the realities among which it exists. This is not due to any greater awareness in terms of the senses; man has many superiors among the animals in this respect. It seems rather to lie in man's ability to manipulate objects with his hands, and related ideas, in the form of words and word-groups, with his mind. The direction of both orders of manipulation is the work of the central nervous system, which is thus able to establish a relationship among its experiences. Physiologically, ideas are undoubtedly the product of sensation and activity; but they also become extremely important in governing activity, once they are established.

Today man has developed a fairly consistent and potentially very useful picture of the world and his relation to it. If his culture is to persist, he must be prepared to make successful adjustments as the need arises; and if his adjustments are to be successful, they must be made on the basis of the most complete and accurate world-picture that science and culture can provide.

But man is not long content (nor able, if he were content) merely to preserve his culture from decay; he seeks better adjustment within the culture and to-

ward the surrounding world, which culture itself is forever changing. Indeed here is the great dilemma of civilization. In adjusting ourselves to the world, we change it. The process is endless.

What can science do to help? It is responsible for many, if not most, of our present material achievements. There is, furthermore, reason to believe that science holds promise of achievements far greater than those of the present, making possible comforts and satisfactions in the greatest abundance for all. The end, of course, is a better society of better individuals, well balanced yet sufficiently dynamic to adjust itself to change, however that change may arise.

This end is not likely to be achieved by the simple process of piling up material invention, without attention to the operation of society itself. The large measure of material advance already secured is not very uniformly available, nor has it produced a society pre-eminent for happiness over those that have gone before. The prodigious use of technical resources and wealth for destruction and the increasing resort to stringent authority to maintain order and provide employment for large segments of the population are unmistakable signs of dangerous social disintegration. Using the suitable analogy, the condition is one not of health but of disease. It may, in fact, be accurately described in the very words by which we define disease, namely, "a condition of disturbed functioning."

THE RESPONSIBLE CONTROL OF HUMAN CULTURAL PROCESSES

Wherever we are dealing with an organized relationship, no matter what, whether clock, animal, or society, disturbance can be adjusted only by an understanding of how the system functions. There is, of course, a chance that we may hit on the right procedure through trial and error, or simple blind luck; but such a chance becomes almost negligible as the mechanism becomes more complex. And certainly society is the most complex of relationships known to us.

As soon, moreover, as the methods of science become turned toward an investigation of the social pattern with the same thoroughness that has been employed toward the remainder of the natural world, certain grave difficulties are encountered. Such studies are extremely laborious and costly, requiring prolonged and liberal support. Notable examples are afforded by the work of former President Hoover's Commission on Social Trends, and by the work of the National Resources Board under President Roosevelt. The Resettlement Administration, the Bureau of the Census, the Bureau of Agricultural Economics, and a number of endowed institutes, sometimes working in cooperation with the government, may also be mentioned. All of this work, however, represents but a beginning in the accumulation of social data. Further-

more, it has the same relation to a formulated science of society that the astronomical tabulations of Tycho Brahe had to the great work of Kepler and others which followed. Until our knowledge of society can be properly formulated, it cannot be available for use. Even then, and most difficult of all, there will remain in society a difference of opinion concerning the choice of the values which this knowledge may be used to conserve or establish. From the very nature of the problem, these choices cannot be disinterested; they will be vigorously, even at times ruthlessly, asserted and enforced.

FAIR PLAY IN THE APPLICATION OF SOCIAL KNOWLEDGE

It follows, I think, that there is little hope of the practical application of a knowledge of society to its own general betterment without a reasonable atmosphere of fair play among conflicting interests. In practice, of course, this is an extremely difficult condition to find, although its existence often is professed. Some form of democracy in which discussion is as little restricted as possible, and in which wealth and privilege on the one hand, or massed stupidity on the other, cannot be marshalled *against* the rest of the community, would seem to be essential.

It will serve to clarify this point if we revert to an example already mentioned—the relation between a balanced agriculture and human nutrition in the United States. One agency is concerned, namely,

the Department of Agriculture, which, fortunately for our purpose, is run on a relatively high plane of public service. Its Bureau of Home Economics has information that more than one sixth of our population is not adequately nourished, as a result of either inadequate or improper diet. Its Bureau of Agricultural Economics has evidence of distress among growers of cotton and cereals, due to both overproduction of those commodities and an inadequate means of distributing them. Yet the Department is pressed to find means to underwrite these distressed producers, and is not free to take the lead in pointing out that their persistence contributes to a dietary unbalance of the American people. Cotton cannot be eaten, and our diet is probably too high in refined cereal for our own good. On the other hand, there is a serious shortage of milk, eggs, butter, meat products, fruit, and vegetables, both in production and in the national diet.

At the very best, in a country so vast and varied as ours, this problem is not simple. It does no good for a farmer in Nebraska to raise meat and poultry if people in New York who need them have not the means to pay the costs of growing, shipping, and distribution.

But the first step in solving a problem is to know that it exists and to be able to state it clearly to ourselves. Science enables society to do this. And indeed it can go much further; at every step it can furnish accurate information which will contribute to a solution.

The men charged with the shaping of our political life are as yet scarcely conscious of the power thus available for the betterment of society; but it exists, and will be placed increasingly at our service as our experience grows.

CHAPTER V

The Community, A Moving Equilibrium

Each Living Organism Is Itself a Community of Units and Groups of Units. In Their Turn All Living Things Tend to Occur in Communities Which Develop Toward Conditions of Equilibrium

---

ORGANIZATION AN ATTRIBUTE OF LIFE

In the preceding chapter we have discussed the human community chiefly with reference to those features which are distinctively human. In spite of their complexity, such features comprise the bulk of our familiar experience and are the point of departure from which we proceed to investigate simpler and more generalized situations. Moreover, as we have seen, it is our human culture which provides us with the means for describing that culture and the world of which it is a part.

It should be, but unfortunately is not, a commonplace of knowledge that human communities have certain characteristics widely shared by communities throughout the world of nature. The human community is, of course, a community of living organisms and represents merely a special case among communities of organisms in general.

Our right to assume this is supported by the course of scientific discovery as applied to man in the past one hundred and fifty years. The existence of unique human levels of activity does not preclude the sharing by man of lower levels. Most of what appears to be really new and distinctive arises from what is simpler. In its mechanical activities the human body is governed by dynamic relations. Its elemental chemical composition is in terms of the familiar chemistry. The compounds which can be isolated from the human body and analyzed are classifiable in terms of organic chemistry. The energy changes in man are consistent with what is known of thermodynamics. The organic functions of man are similar to those of all living organisms. The structural units of his body, the cells, are in their general features the same as those which obtain in all living organisms. The structural combination of cells, that is, the morphology of the human body, which is itself a form of community, grades without too abrupt transition out of the morphology of the higher vertebrates, indicating a relationship which is further supported by the meager fossil evidence.

Even the sacrosanct characteristics of the human mind are being shown, by recent comparative studies of the anthropoids or manlike apes,[1] to differ in degree rather than in kind from those of other animals. One

[1] Cf. Yerkes, R. M. *Modes of Behavioral Adaptation in Chimpanzee*, . . . Johns Hopkins University, Baltimore, 1934.

can say, if he prefers, that the quantitative differences are of an order to establish a new range of qualities; but the fact remains that the similarities are fundamental. Thus it is scarcely too much to suppose that as man's individual attributes have a biological basis, and a physical basis back of that, so his social attributes have a similar background, however distinctive the levels to which they attain.

There is, by the way, an interesting trend toward the use of the term *sociology* in the study of plant and animal communities.[2]

The human individual is a community of interdependent cells, so completely interdependent and producing so perfect a community integration that we speak of the complex as an *individual.*

Likewise every other living organism is a community of lesser units. In the multicellular organisms the units are cells. These may be only slightly, if at all, interdependent, merely forming a cell-colony, or they may be cooperatively active, to form a well-integrated cell-state, which we call the individual.

Each single cell of the cell-colony or many-celled individual, and each non-cellular or so-called one-celled organism is similarly composed of interacting units and groups of units; e.g., nucleus, cytoplasm, chromosomes, genes, mitochondria, etc.

Among the multicellular organisms during the

[2] Cf. Braun-Blanquet, J. *Plant Sociology,* rev. ed. McGraw-Hill Book Co., New York, 1932.

course of evolution and under differing environments, many different successions of increasingly complex and integrated cell-communities have appeared, resulting in many thousands of species, or types of cell-community.

Thus, structurally the individual is a very real thing. Yet in terms of its broader relationships, the solitary plant or animal is an abstraction, at most a laboratory preparation. The old Hindu proverb, "One tiger to a hill," really means two tigers, one male and one female, with the young in custody until they can fend for themselves. And when the latter leave, their new abode is spaced in relation to the rest of the tiger community. Even the distance between hilltops is not the master factor; for unless the tiger is unique among carnivores, his abundance and distribution are controlled by that of his food. And such food supply in turn depends upon the structure and composition of the living community of which the tiger is a part.

Human language is rich in expressions which indicate the groupings of organisms in nature. "Herd," "forest," "steppe," "pack," are a few of the more familiar instances. It is a little difficult to understand why the scientific significance of anything so well known as the aggregations of life has been so slowly grasped. The new tools of description and analysis were first directed toward the individual plant and animal: long thereafter the facts of interdependence and cooperation were neglected. And, of course, it is

true that life had to be catalogued and studied geographically before much progress could be made in studying its social organization.

THE PATTERN OF COMMUNITIES IN SPACE

The first, naïve impression made by life upon the traveler is its diversity. This can be, even to the somewhat trained eye, quite bewildering, as I have had frequent occasion to know. I was, for example, transferred to an army post in the Florida wilderness in 1918. The landscape, which had not been much altered by man, seemed to be utter confusion until I had viewed it from the air. From that perspective its order became apparent—largely a matter of relation to water levels. The interpretation so worked out, I found later, agrees essentially with the results of scientists who had been able to give the matter their full attention.

A similar, but of course much more systematic, perspective on the diversity of world-patterns of plant and animal life has been arrived at by the labors of geographers and naturalists generally. And at the other extreme, the detailed analyses of local landscapes by botanists and zoologists have given us evidence of the existence of patterns on the minute scale.

What we have, in effect, is pattern within pattern—a hierarchy of communities, running from the entire world-community in all its diversity, down through

lesser subdivisions, even including the individual. The difficulty of description or classification under such circumstances is plain and has, to date, not been too completely met.

Because vegetation is fixed and visible, whereas animals can move and conceal themselves, and because animals depend upon plants, the most satisfactory classifications of communities of organisms today are based upon vegetation. To begin with, we have:

- World Vegetation
  - Terrestrial—Tundra (treeless arctic and alpine)
    - Forest
    - Grassland
    - Scrub (semi-arid woody shrubs)
    - Desert
  - Aquatic —Marine (salt water)
    - Fresh-water

Taking certain of these in more detail we have:

- Forest —Deciduous—Temperate
  - Tropical (Monsoon)
  - Evergreen—Coniferous—Cold dwarf "taiga"
    - Temperate
    - Tropical rain forest
- Grassland —Prairie or subhumid steppe
  - Plains or semi-arid steppe
- Marine —Benthon—anchored vegetation
  - Plankton—floating vegetation

Should we attempt further to divide the temperate deciduous forest, for example, we would find it necessary to do so in terms of geographical areas and the particular kinds of trees which are dominant in particular places. And from this point on the classification becomes very intricate indeed. For example,

Temperate Deciduous Forest
  North American Hardwoods
    More humid phase—Beech—Maple—Birch
      Mixed Southern Hardwoods
    Less humid phase —Oak—Hickory
      Red Oak—Linden
      Bur Oak
      Scrub Oaks, etc.

Moreover, this brief example is neither complete nor generally agreed upon. It merely serves to illustrate the character of community classification.

At this point it should be mentioned that, in addition to the conspicuous dominants, there are less abundant and less conspicuous forms of life which are quite as much a part of the system, and that among all of these organisms, plant and animal, there are interrelationships of varying degree. In other words, the minor community exhibits organization, while the relationship whereby these are grouped into successively larger communities also can be regarded as organization. Certainly this is a general attribute of life in the aggregate, as it is of life in the individual.

Apart from its division into land and water, the earth is charted by a dual system. One is mathematical, the system of latitude and longitude; the other political, the system of states, etc. When we compare the pattern of living communities with these other systems of reference, the confusion is merely multiplied. There is absolutely nothing on a conventional map of the United States to indicate where the great pine forests of the South, the short grass plains of the West, or any other great natural area prevails. Curiously enough, however, if we replace the usual geometric and political maps with those showing cultural data, then our natural community areas begin to reappear. Take illiteracy, for example; its greatest prevalence is largely coextensive with the southern pine area, and cotton-growing with both. Farm abandonment caused by wind erosion, if mapped, gives one a fair outline of the high plains. Distress occasioned by speculative cereal farming is, in general, a grassland phenomenon. These things disregard state boundaries and polar coordinates alike.

THE ANALYSIS OF COMMUNITY PATTERNS

It follows that to describe the pattern of living communities on earth is a matter having practical difficulties, in terms of the maps to which we are accustomed. But the difficulty does not stop there. The analysis of greater into lesser communities can be carried to an almost endless degree of refinement. Each old rotting

log, for example, is seen to support its own distinctive community of organisms, if we look into the matter. Clearly, the scale of our description must determine the refinement of our analysis; and in any case the problem is exceedingly complex.

We get a useful analogy if we think of the multitude of the stars and other bodies in the heavens. These can be catalogued and charted, but such information is of little service to the human mind in grasping their relationships. Such an understanding comes rather from a knowledge of the galaxies and systems which compose them, the forces which sustain them in their relationship, and the processes of their development. In other words, the study of astronomy is not merely a study of position, but far more a study of dynamic relationship and genetic history. In that way, scientific generalization becomes an exceedingly powerful tool of description and understanding.

And so it is in the description of natural communities of plants and animals. The great difficulty is that we have no such precise and beautiful method as the calculus at our disposal for the task. Nor do we have such long continued and laboriously detailed compilations of knowledge as those of the astronomer on which to work; even if we did, we could not avoid the fact that man has produced enormous changes in the landscape, destroying a great deal of significant evidence.

We may begin by pointing out that living com-

munities are the expression of a moving equilibrium among a number of highly complex variables which themselves represent moving equilibriums.

EVOLUTION

1. First and foremost, the living plants and animals which compose the communities are those made available at a given time and place by the process of *evolution*. In terms of the rate of evolution, that process is generally so deliberate that in many of our practical problems today we ignore it. We are more concerned with what it has given us than with what it is doing to us and the rest of nature.

Yet through it we have the varied faunas and floras of different parts of the world. And we have ample evidence from the past that old communities have been broken up by the coming of new evolutionary material. Sometimes this new material may have developed on the spot, at other times it may have evolved elsewhere and migrated in.

MIGRATION

2. Indeed, *migration* as a means of spreading the effect of evolution is a practical problem which is before our eyes. The Cactus moved from America to Algeria and Australia, the English Sparrow brought to America, and likewise the Chestnut Bark Disease, are very evident illustrations. Our own displacement of the American Indian, however, is not due to the

physical evolution, relatively slight, which separates him from the European. It illustrates the competition of cultures, rather than races, which have evolved in different places before being brought into competition by migration.

No understanding of the present pattern of life upon the earth is possible without an understanding of the nature of migration and the related problem of isolation. Thus to the student of life, a knowledge of barriers, boundaries, pathways, physical, chemical, and climatic conditions during the earth's history is supremely important. With it must go an understanding of the means of movement and dispersal of plants and animals, and their capacity to meet changing conditions. Only man has been able to encounter radically new conditions without a corresponding degree of physical evolution. In his case the need has been met by the change, or evolution, of his cultural processes.

CLIMATE

3. In the next place, communities are composed of species as assorted by climate. Significant *shifts of climate* may occur somewhat more rapidly than the process which we usually designate as evolution of species. When that is the case, the result is a migration or extinction of existing species. But the major climatic cycles are of the evolutionary order of magnitude, and often are accompanied by readjustments involving new species as well as older ones.

Turning our attention, however, to the existing pattern of climate, we find that it is expressed in terms of the major communities into which the world-community is divided—forest, grassland, scrub, desert, and tundra, with their characteristic animal life and eventually their proper human culture. These major communities, often called "formations," are recognizable in terms of their structure, no matter what species may be present to compose them on a given continent. Moreover, as the climatic studies of Thornthwaite[3] and others testify, each can be correlated with a major subdivision of climate. Very simply this might be expressed,

Tundra—so cold that moisture differences are largely offset
Forest—humid
Grassland—subhumid
Scrub—semi-arid
Desert—arid

Obviously, a humid forest region might be hot, temperate, or cool, leading us to expect differences in the forest types, and in fact we do find them. Moreover, the boundaries between climatic provinces are seldom sharp; neither are those between formations. Indeed, these marginal regions are very profitable to study. In them we may find little islands of life which

[3] Thornthwaite, C. W. "Climates of the Earth." *Geographical Review*, Vol. 23, No. 3, pp. 433–440, July, 1933.

hang on, not so much because the climate is any longer entirely appropriate to them as for historical reasons. In nature, as in law, possession is an advantage not to be lightly set aside. At other places along these margins we find that some feature of topography, such as the slope of a hill, or some soil characteristic, or a matter of water supply, may serve to throw the balance in favor of an outlier of one or the other of the two contiguous formations. The northeast slope of Rich Mountain, in Arkansas, has a forest which might be growing in Indiana; the southwest face has a cover that might be found in central Oklahoma.

TOPOGRAPHY

4. Having considered evolution, migration, and climate, let us consider the next variable factor which expresses itself in community pattern. This fourth variable is the matter of *topographic change*—a cyclic process, irresistible and, like other geologic processes, often immeasurably slow, yet at times so rapid that we can see it under way. It is the process of erosion and deposit, renewed at times by uplift. The end toward which it works is a nearly level condition of uniform drainage and slope, in which hills have been worn away and valleys filled. This end is known as the peneplain.

As compared to the uniformity of the peneplain, a youthful topography is marked by sharp contrast between upland and depression, and by uneven distribu-

tion of available water. As a result, the impact of climate on a young landscape is quite varied, and the contrasts in living communities over its surface are correspondingly vivid. By its very nature, it is less stable than a mature topography, its living cover more transient, more precariously seated. The analogy with youth and maturity in a living organism is obvious. There is an inevitable succession of communities with the course of topographic change, just as there is a succession with evolution or with climatic change.

SOIL

5. The fifth great variable affecting the community pattern is the soil, or rather, the *process of soil development*. Even in the absence of life, the earth's surface as exposed to the play of atmospheric factors undergoes physical and chemical changes known as weathering. As life moves into an area, the process continues. The crumbling and change of surface rock is assisted by the action of animals and plants. Their activity also results in the accumulation of carbon compounds, designated as humus. This humus not only modifies the properties of the weathered rock profoundly but represents a growing reservoir of chemical energy for the microorganisms which are essential to a productive soil. The course of soil development is registered in the soil profile—a vertical section running down from the surface and affording a gauge, not only of the maturity of the soil, but even of the climate and other

conditions which have attended its development. Capacity to support a rich and varied community is measured largely by the degree of soil maturity. Obviously there is a succession within the community as the soil matures.

THE DEVELOPMENT OF COMMUNITIES

6. The sixth great variable in determining the character of communities is the actual development of the community itself—a process often described by the simple term "succession," but to which we can refer more accurately as *biological stabilization.* This process of stabilization is to be seen clearly when life invades a new area, such as a bare rock surface or a lifeless body of water. But it also takes place whenever the balance of an existing community has been upset by evolutionary, climatic, topographic, or soil changes, however induced.[4]

An idealized account of stabilization will be found in considerable detail in Sears: *This Is Our World* (pp. 197–201). We may say, however, that when a new area is invaded or colonized, the first organisms to appear constitute a pioneer community. The pioneers themselves must be able to meet conditions which have not been tempered by the presence and activity of preceding communities. In the case of plants, for example, pioneers must be tolerant of extreme light,

[4] Clements, Frederic E. *Plant Succession.* Published by the Carnegie Institution of Washington, 1916.

extremes of moisture, and generally of an unbalanced mineral supply. We call them "hardy" or "tough." The animals must be either casual visitors or species which are dependent, more or less directly, upon the pioneer plants.

As time goes on, these pioneers modify the habitat to such an extent that it becomes an environment in which other organisms are more efficient than the pioneers. Thus the latter are replaced. Meanwhile, the chains of interdependence among the species present become more closely interwoven. Soil begins to form, conditions of light, moisture, mineral supply, and organic activity become modified and tempered until a relatively stable condition, known as the climax, is developed. When this is reached, the organisms making up the community are able not only to function with great effectiveness but to reproduce themselves in place instead of being replaced by other species. There is an effective balance, or equilibrium, within the community, and between the community and the physical environment. Such fairly stabilized climax communities represent a slowly developed interrelationship of organisms with the particular physical environmental complex. Since any physical environment is a complex, this natural climax community is our best expression of it, serving far better than any descriptive label to characterize the physical environment.

Because succession toward the climax involves a

more complete integration of life, soil, and climate and is in fact accompanied by a steady development of the soil itself, there is reason to believe that it represents a progress toward maximum net yield of living organisms from the particular habitat. This is borne out by many observations supported by some quantitative data, although more records are needed.

Naturally the kind of organisms whose abundance is favored by climax conditions depends upon the living material made available by evolution, and is limited to those which are suited to the climax. Weeds and crop plants are not part of a natural climax, nor are domestic animals and household pests, since these thrive in man-made conditions.

The climax stage represents a slowing down of the rate of change of composition but not of biological activity. Species reproduce themselves instead of giving way to other species, but only as long as they, under the circumstances, are the most efficient organisms in their conversion of energy and materials. When evolution, migration, or change in soil or climate make this no longer true, they are likely to be replaced. We must conceive of the climax community, then, not as a static affair but as a condition of dynamic biological equilibrium.

This process of stabilization exhibits the curious paradox of "tough" species being replaced by others decidedly less hardy in relation to an untempered environment. The explanation lies in the fact that, in a

tempered environment, the latter are much more efficient. There is an interesting and profitable analogy in the contrast between pioneer and civilized human communities, and the type of individual successful in each. But in the case of human invasion, man *must* be preceded by other organisms, and generally by lower cultural levels of his own kind. And the pioneer human culture is not followed by other species but by successively more highly organized cultures of humanity, until a balance is approximated. At the biological level, of course, the developing human community involves organisms other than men. Body lice and weed seeds, for example, might come in earlier than the brown rat and venereal parasites if the invasion were overland; while a marine invasion might reverse the order, certainly for the rat. Cultivated plants and domestic animals are a part of the community, too.

Actually, of course, human community formation belongs in the category of stabilizations made necessary by evolutionary change—migration being its instrument. Whether involving man or not, such changes bring in new competitions, upsetting old, often highly effective, equilibriums, and giving rise to new ones.

The same may be said of changes in topography, soil, or climate. These disturb the even course of previously balanced communities, at times throwing conditions back to a definitely pioneer level, at other times permitting a gradual replacement of species in the

previous climax by others better fitted to the new conditions. Such noncatastrophic stabilization (what a mouth-filling expression!) must have occurred, once life became established, during much of the fifteen thousand years or more since late postglacial times.

At the cost of repetition, it must be emphasized that the members of a climax community are thoroughly interdependent. Invisible plants and animals, microorganisms and soil-dwellers, are as much a part of the climax community as the conspicuous, aboveground dominants. Very generally the latter could not survive without the former. And insofar as stable human communities do not take a realistic view of this fact, their own stability is an illusion.

MAN AS A FACTOR

It must further be noted that the effect of human invasion is not confined to a destruction of the previous climax. It very largely modifies the conditions which made that climax possible. It produces especially changes in soil and topography under which any highly efficient and organized community may become impossible, including, of course, any stabilized human community of a high level. Dramatic examples of this process may be seen in Asia Minor and along much of the Mediterranean coast. And the tremendous access of cultural energy in Western Europe following the discovery of America has its visible consequence in the widening area of depletion in the United States.

An understanding of this relationship greatly illuminates modern imperialistic war. Modern war has become much more than a destruction of human lives. It is a destruction of the ecological potential on both sides. It frequently costs each combatant nation more than a million dollars a day, much of which represents a forced draft upon the cultural accumulation, based in turn upon soil and minerals. Its success is gauged by the degree to which it destroys such accumulation on the other side. And if the territory gained is occupied by a culture which is already living near the margin of its capacity, what more is to be gained than new recruits for similar enterprises in the future? The process is strikingly like the exploitation of some of the new, deep oil fields, where more money, literally, goes into the ground than ever comes out. Some few reap benefits, but the bulk of the participants must lose. Repudiated billions of war debt and the loss of ten million lives do not adequately measure the real destruction wrought by the World War; in fact, they serve to obscure its true nature. The point to be recognized is that Western civilization, both in Europe and in America, is largely an expression of the tremendous ecological potential of the rapidly exploited Americas. The World War itself actually speeded up this exploitation, in potash beds, wheat fields, and spruce forests, not to mention its direct effect upon the already hard-pressed continent of Europe.[5]

[5] Furnas, C. C. *The Storehouse of Civilization.* In press.

However much the situation has been made worse by continuing cultural conflict since the end of armed struggle in 1918, the profound cultural regression of the Western World today has some of its roots in the violent lowering of ecological potential caused by the destruction and disorganization inherent in war itself.

The effect of war, after all, is not unlike that of the destruction of soil by exploitation which produces unchecked erosion, whether by water or by wind. The process destroys not only the existing ecological relations of the living organisms, within and between communities, but the organisms themselves. This is followed by a period of stagnation, and the invasion of new types of plants and animals, which by their organization are more efficient under the new conditions and succeed under them.

In similar fashion, following the upset of equilibrium by war, new and more efficient, if not ethically more admirable, cultural patterns develop; e.g., totalitarianism in one or another of its forms. In this way the community adjusts itself to survive in the habitat, impoverished as it is by war.

INTERACTION OF COMMUNITY FACTORS

We must note, in conclusion, certain points with respect to the theory of community development. We have said that living communities are an expression of biological stabilization—itself a genetic process—with respect to several complex variables, to wit: evolution,

climate, topography, and soil. The possible phases of any one of the four are, to put it mildly, numerous, while the possible combinations quite evade our understanding. The practical evidence of this is the multiplicity and complexity of living communities over the earth. Under such circumstances, what hope of order and simplification is there?

To begin with, since the changes of evolution and climate are extremely slow in terms of our record, we can assume that the surface of the earth falls into fairly definite climatic provinces, each with a fairly definite fauna and flora—its given evolutionary material. The facts do little practical violence to this assumption.

Next, we may assume that within each such province topographic change is under way, giving rise to land forms of varying degrees of maturity, but all developing toward a mature condition unless rejuvenation occurs. We may also assume that where the mature condition exists, it represents almost perfect equilibrium with climate. And we may further assume that, at all stages of maturity, biological processes and soil formation are at work, moving toward relative stability under the particular conditions. But unless these processes occur on mature topography, both soil and organisms will be modified by the further course of topographic change. The limit of this change will be reached only when the topography matures, if it ever does.

Thus, taking our evolutionary material and climate

as relatively fixed, we may say that within each province all of the diversity of living communities represents a series of changes, or stages toward an ideal limit. This limit is a stabilized climax, on mature topography, covered with a mature soil profile, in equilibrium with the given climate, fauna and flora. All other communities may be judged and designated in terms of their degree of approach to that limit. This task, while difficult, is by no means hopeless, as practical experience in the field shows.

Once this viewpoint is understood, the present confusion in the classification of communities and in the use of the term *climax* is on the way to being ended. Furthermore, a very practical concept in the utilization of the landscape by man becomes available; for in nature the theoretical climax expresses, as we have said, the most effective possible relationship of life, climate, topography, and soil in producing the means of continuing life. Whatever promotes an approach to this ideal increases the capacity of the earth to support life steadily and continuously; whatever delays or reverses the process lessens that capacity.

Now man, since he is an animal, is dependent upon the efficient, continuous elaboration of raw materials into foods by plants and the continuation of this process by other animals. It is to his interest to promote through his culture a pattern of relationships which, like the climax community, represents as effective as possible a means of conversion of energy and materials

for his use. This is one of the great problems of modern civilization, and is vastly complicated.

Man must have room for his cities, his highways, and many other works, all at the expense of productive land. And he must have the products of cultivated fields. Such fields are seldom handled to simulate the constructive processes of natural habitats. Well-balanced pasture areas and well-managed forest are better in this respect. The area of both needs to be greatly increased, at the expense of ill-managed crop land. In a suitable pattern of land use and a skillful regime of land management, man has the means of working toward a new type of equilibrium, frankly controlled for the permanent welfare of himself, now the dominant organism.

CHAPTER VI

The Working Organism in the Community

Communities Arise Through the Interaction of Living Organisms with Environment. The Role of Any Organism Depends upon Its Inherited Capacities as These Develop under the Given Conditions

---

ORGANISM AND COMMUNITY

We have just seen that biological succession is the resultant of the processes by which communities of living things arise and develop. This succession is inevitable because of the changing character of living things, climate, landscape, soil, and because of the complexity of interaction and adjustment among them all. Such succession works toward relative equilibrium, expressing itself by progressively more complete and stable organization among the members of the community.

The world-community as it stands today has arisen through evolutionary succession in which more specialized organisms have steadily replaced those which were less specialized. Its stability is relatively great—so much so that human history contains the record of only a few organisms which have actually become extinct after their discovery by modern man. And while

man has developed many new varieties and modifications of the plants and animals which he found, the general progress of evolution, except as stimulated in special experiments by clever manipulators, is like the curvature of the earth, so gradual that it passes unobserved.

The first really plausible statement of evolution was that of Darwin and Wallace, which postulated that organisms vary and that the resulting fitness to environment determines which variations survive. We have already considered the inanimate environment within whose framework this process goes on, and we shall later consider it in greater detail. It is necessary to remember, however, as mentioned in a previous chapter, that living organisms have been an exceedingly important part of the environment for their fellows.

The fossil record is the sketchiest sort of an outline of the history of life, yet it is quite definite on the point just stated. The sea was the cradle, if not the place of origin, of life; and simple forms of life there preceded the larger and more complex forms dependent upon them. Land vegetation preceded land animals, and carnivorous animals followed the vegetarians. As new host plants and animals multiplied, so did the parasites to which they afforded the means of living. The elaboration of the groups of flowering plants and insects, whose welfare has been so thoroughly interwoven, has gone forward almost as one process.

The present dominance of the warm-blooded mammals is conditioned upon the existence of the higher seed plants, while man, the newcomer, is the beneficiary of the whole long series of events. Simple and obvious as these facts may be, they are nevertheless extremely important.

THE PROBLEM OF FITNESS

Even though the earth and its inhabitants may furnish conditions suitable to a given species, in most cases the conditions satisfactory for such a species are found only in definitely limited areas. Man, through his cultural achievements, has come nearer to overcoming this limitation than any other species. A Negro accompanied Admiral Peary to the North Pole; it may be doubted, however, if an Eskimo would survive long in equatorial Africa. Be that as it may, an organism which is to function successfully and reproduce its kind must have the proper environment. And in proportion as organisms have similar requirements, they tend to be grouped together.

The science of physiology is largely concerned with a study of the conditions necessary to normal behavior in plants and animals. And in the case of every organism studied, the physiologist finds that, in its relation to the various factors of environment, there are limits beyond which survival is impossible. Well within those limits are the conditions necessary to successful and normal behavior. Temperature is one of the most fa-

miliar and graphic of these factors. Through what a small fraction of the interval between absolute zero and the sun's temperature can life survive! Moisture, light, kind, proportion, and pressure of gases are among the other, simpler factors. But the requirements are not always physical; certain orchid seeds will not germinate in nature in the absence of appropriate fungi. In this instance the fungi become a part of the required complex of conditions, in addition to suitable light, temperature, moisture, and soil.

It is important to understand that the requirements make up a complex. Some elements can have an effect only by their presence or absence, as the fungi just mentioned; others by their intensity or degree. And in such cases the degree required may depend upon other factors in the complex. A plant may be able to survive with less moisture if the temperature remains low than if it becomes high, or to endure more than normal shade if it has sufficient water. Sodium may substitute to a small extent for potassium in plant nutrition. We see this principle exemplified in the case of animals and plants grown out of their natural range; especial care must be taken to compensate for the great variation from their normally required complex.

Although the factors influencing an organism make up a complex, with some chance for variation and compensation, there is one principle which seems to apply pretty consistently. This principle is known to most of us in the form of a proverb: "The chain is no

stronger than its weakest link." Applied to the environmental complex it might be stated as follows: "The complex is no more favorable to an organism than its least favorable factor permits it to be."

Thus, early in the eighteenth century, Baron Justus von Liebig found that in using chemical fertilizers to promote plant growth, no benefit could be obtained by increased amounts of certain substances if others remained deficient. To describe this effect he spoke of the "Law of the Minimum." Soon after 1900, Professor F. F. Blackman, at Cambridge, found in studying the process of food manufacture in green plants that the rate of the process was limited by the least favorable of a number of necessary factors. This principle he designated as the "Theory of Limiting Factors," a term still widely used.[1]

And so, in the study of the individual organism and of communities as well, the search for the limiting factor in any particular case has become an important matter of scientific routine. Thus in the continental interior, where moisture is relatively scarce, we frequently find it a limiting factor to the growth, say, of forest. In New England, where moisture is abundant, we may have to search for some other limiting factor, perhaps in soil chemistry. For animals, food is a most obvious limiting factor and temperature is another. The presence of the tsetse fly, which carries

[1] Blackman, F. F. "Optima and Limiting Factors." *Annals of Botany*, Vol. 19, pp. 281–295, April, 1905.

sleeping sickness, is a definite factor in parts of Africa, both to man and to certain of his domestic animals. In its turn, however, the distribution of this fly is controlled by climatic limitations.

The requirements of a species are as distinctive as its structural peculiarities, and are called "specific." Their groundwork lies in the hereditary make-up. Within the species varieties may differ considerably, as we see by comparing the long- and short-season sweet corn, or the Chihuahua (Mexican hairless dog) and the German sheep dog. And, of course, individuals of the variety may differ somewhat in their inherited pattern of requirements.

On the basis of this inherited pattern, however, the individual may be modified during development in significant ways both in structure and in behavior. It is often said, whether truly or not, that one of the surprises of the American War between the States was the greater marching ability of the city-bred men, accustomed to pounding pavements all of their lives. For example, again, a magpie accustomed from hatching to hand-feeding is likely to be quite helpless without a human sponsor. And fruit trees or other plants can be hardened to frost by reducing their water content. It is therefore important to note that the requirements of a given plant and animal are not phenomena of a mystical order, but can generally, with sufficient study, be related to definite peculiarities of structure or function—sometimes, indeed, to very simple phys-

ical and chemical features of the organism. Their investigation has been pushed to a notable degree in the case of certain cultivated crops, and of the human animal himself.

THE ORGANISM AS AN ACTIVE FACTOR

The role of plant or animal in a community, however, amounts to a good deal more than its fitness to the conditions which place it there. It is a functioning unit in the community, modifying it by its presence, and forming a part of the environment of its fellows, as we have noted. Its make-up, as inherited and developed, determines not only what it can endure but what it can do.

Thus the lichen, growing on a bare rock surface, can endure the extremes of light and temperature, live in spite of great desiccation, and use moisture when it comes as a means of growth. But it may also produce acids which dissolve apart the rock fragments of granite; and it may, by shrinking and swelling with the changes in its moisture content, actually split off tiny bits of rock to which it is tightly fastened.

Eventually the lichen dies and is broken away, at least in its oldest portion. Its work, however, does not cease, for the dead fragments and mingled rock particles are washed into crevices, and soil is born. Into this soil come ants and other invertebrates, who can thrive in its darkness and moisture, and who rework the nascent soil, bringing in material from the outside.

Roots enter, not only enduring the conditions they find, but further altering them.

We see the same principle exemplified by the weeds which spring up on a barren bank of clay. These weeds can withstand the intense sunlight, the scanty moisture, and the raw mineral supply, however unbalanced it may be. But the weeds provide shade, contribute waste material, and feed leaf-eating beetles and stalk borers. By their presence and activity they modify the environment. It ceases to be a mere barren bank of clay, and becomes hospitable to more permanent types of organism than the weeds which first invaded it.

Just as the requirements of an organism vary with the species, so does the role which it plays. Each is a problem in itself to be studied diligently—a task that has barely begun, considering that there may be upwards of a million species, more than two thirds of which are animals. It is difficult to make even the most general statements, but the attempt is necessary.

Green plants are able to manufacture food out of the inorganic materials of earth and air, utilizing the energy of the sun for that purpose. Some of this food is utilized by the plants which make it. Such food is also the source of nutrition for plants which are not green, and for animals. The sole exception known is afforded by certain bacteria which, lacking chlorophyll, can utilize chemical energy from mineral compounds of iron, sulfur, and nitrogen to manufacture

simple foods. But these bacteria do not loom large in the usual community of living things, although they produce important chemical effects, and are significant in our studies of life in its simplest possible terms.

It follows that green plants are the actual basis of the living community as we know it. The non-green plants, most of which are known as fungi, make their living variously. Those few which manufacture food have already been mentioned. Of the others, many utilize dead organic material, producing the effects which we know as putrefaction, decay, or fermentation. The net result of these processes is to break down the excreta and remains of organisms, making their materials available in various ways to new generations of plants and animals.

Others of the non-green plants attack living plants and animals directly, the result being a condition of disease within the host. The action of disease is an extremely important factor within the community. Frequently it amounts to little more than making the parasite a member of the community, living at the expense of other species without seriously interfering with them like the common run of parasites in human society. At other times it becomes a powerful selective agency, eliminating susceptible species or varieties. And, added to the inevitable breakdown which results from old age, the action of disease speeds up the passing of old generations to make way for the new.

ANIMAL COMMUNITIES PRESENT INTRICATE RELATIONSHIPS

Turning to the consideration of animals, we can say that their most obvious role in the community is to live, as best they can, on the food which the plants provide. This, of course, may involve relationships which are very intricate in their detail. The famous relationship between the number of elderly spinsters in England and the prosperity of agriculture in Australia is a case in point. Australia depended upon the purchase of English-grown clover seed at a reasonable price to grow the legume necessary for nitrogen fixation and soil fertility. Clover sets seed only when pollinated by bumblebees. The bees' nests are robbed by field mice. Cats kill field mice, and lonely ladies cherish cats. Even if one reserve his opinion of the literal truth of this particular sequence, the records of natural history are full of others quite as elaborate and free, moreover, from the scientific peril of humor, real or attempted.

Because of the complexity of animal behavior, including general motility, and the enormous number of animal species, the study of their ecology affords an almost unlimited field. Actual food requirements are merely the basis for intricate behavior patterns, expressed by means of unconditioned reflexes (instinct) among the lower animals, and involving a widening circle of conditioned reflexes (learned behavior) as we

ascend the scale of higher vertebrate life, culminating, of course, in man and his culture.

RELATIONSHIPS AMONG ORGANISMS

Animals may simply feed upon plants, and be fairly indifferent to the kind used. Others are highly selective, like the panda which must have its bamboo shoots. Those which are most selective are, by that fact, highly restricted in their behavior. The larva of the *Pronuba* moth must feed upon the pods of the Yucca plant, which in its turn cannot ordinarily form seed without the aid of this moth. Perhaps the extreme example is afforded by the gall-making insects whose larvae stimulate an abnormal growth of the plant tissues on which they are deposited. This growth, unlike anything the plant can produce without this particular stimulus, affords both food and shelter to the developing larva. Frequently the gall-maker itself is accompanied by a number of inquilines, or satellites of other species, who also use the gall, and, of course, both may have their parasites as well. Thus, within the gall, there may arise a minuscule and transient community.

Carnivores, like vegetarian animals, may have a wide range of diet, or be fairly selective. But as the degree of choice of food narrows, the carnivore, like the vegetarian, becomes more specialized in structure and behavior. The extreme development here is the *parasite*, delicately adjusted to the habits of its host.

These parasites, as distinct from predators who kill and eat, attach themselves to the host animal, either temporarily, as does the mosquito, or permanently, as does the tapeworm. It is estimated that about one half of the animal kingdom lives parasitically. And the parasitized animal, like the fungus-ridden plant, is pathological, or diseased to varying degrees, depending upon the effects produced by the parasite and the severity of infestation.

Both plant and animal realms present striking illustrations of *symbiosis*, a more or less mutually beneficial relation between two species of organism. The lichen, composed of microscopic green plants and of fungi which envelop them, is an arrangement of this sort. So is the system afforded by legumes and the nitrogen-fixing bacteria which form nodules on their roots, obtaining carbohydrates in exchange for nitrates. Cowbird and cattle, sea anemone and hermit crab, crocodile bird and crocodile, ants and plant lice, are all further examples of symbiotic relationship as it obtains among animals. Moreover, between the plant and animal realms, a remarkable instance is afforded by insects which secure nectar and at the same time transport pollen. It seems likely that a high degree of symbiosis is a mark of evolutionary specialization, no less than of a stabilized community.

There are, of course, within the community many mutual relationships which are less striking, more casual in character. Grazing animals carry a good deal

of seed about. In fact, one of the most practicable ways to plant buffalo grass on the western plains is to allow it to go to seed, and turn the cattle into it, and then allow them to roam over the area to be planted. Some seeds actually germinate better for having passed through the digestive tract of an animal.

A quite different, but extremely important, type of mutual relationship within the community is competition. The principle involved is simple—competition is keenest between species whose requirements are most nearly identical. It follows that competition must reach its climax within the species. In plants, which are immobile, this results in spacing, generally determined by root competition, but also influenced by the competition of crowns for light. The plants of the desert are widely spaced, those of the forest and grassland less so. Those plants whose roots "feed" at different levels often grow well at rather close quarters if other conditions are favorable.

Among animals, notably those which are gregarious, this problem of similar requirements throughout the group is met by migration of some sort. There is also an inevitable spacing between the feeding groups, and among the members of so-called solitary species, as in the case of the tiger mentioned earlier. Spacing is likewise characteristic of many species of birds during the nesting season when the demands for food are great.

Underlying the question of competition is that of

population growth in relation to the means of subsistence. The general theory of population growth is quite simple, being based upon the compound interest law. Under favorable conditions a new population will for a time increase in geometric ratio, but ultimately the rate slows down and the population becomes static, barring minor fluctuations, new sources of food, or disaster. As a population approaches its limit, the slowing down seems not so often due to increased mortality as might be expected; instead the rate of reproduction tends to decrease with greater severity of competition. Indeed, there is no other mechanism to lessen the effect of competition within a freely interbreeding group, for genetics often finds that within such a group the trend is toward a uniformity of type and requirement, instead of toward such variation as might lessen competition.

Different species compete in those respects in which they share similarity of requirement. To a great extent, the structural pattern within a community is determined (*a*) by competition among the dominant organisms, (*b*) by the freedom left for subordinate organisms which compete among themselves for the space or other necessities which are left, (*c*) by mutual, parasitic, and other types of dependent relation thereby made possible. Plants, for example, grow more thickly in a meadow than in a tilled field because the various species do not root at the same level, nor form their crowns at the same height. Obviously, too, the taller

must be able to thrive in stronger light than the shorter require.

The organic mechanisms by which plants and animals adjust themselves to the range of relationships we have briefly outlined are multitudinous. Their study is an engrossing one, and comprises the field of the ecology of the individual.

CHAPTER VII

The Nature of Ecology

Ecology Is the Testing and Synthesis of Whatever Can Be Known about Life and Environment in Order to Interpret Their Relationships in Scientific Terms

---

THE ECOLOGIST AT WORK

WHILE all life is the province of the biologist, the great bulk of biological work is, in active practice, focused upon the individual organism as a specimen. Whether the specimen be living or dead, its structure, behavior, and classification among other living things are studied by the methods of analysis and experiment. In this way an immense store of extremely important knowledge has been developed.

Such knowledge, however, does not represent a central attack on the problem of the living organism at work in its natural environment among other living organisms and amid the forces and materials of the inanimate world. Much of that knowledge is indispensable to a solution of this problem; and if the studies of behavior extend, as they frequently do, to an investigation of life history and habits of nutrition and of reproduction, the line separating ecology from other knowledge has been definitely crossed.

This has been the usual method of approach in animal ecology. And a continued attention to the round of life of the animal soon brings into focus questions of disease, of competition, and of numerous relations to other organisms of the same and of other species. Gradually the fact of interdependence develops, and with it a sense of the importance, both to the individual and to the community, of conditions in the physical world.

With plants, on the other hand, the direction of approach is generally quite reversed. The reproductive and subsistence relations of plants and their life histories are more generalized, at least to the ordinary observer. Since plants as a rule do not have the power of locomotion, the striking thing about plant life is not the activity of the individual, but the massed development of the group. Despite the old saw of not being able to see the woods for the trees, the forest, the grassland, or the scrub is a far more striking phenomenon than the individual plants composing it. Not infrequently, too, the plant community shows an obvious relation to certain conditions of environment, notably the water table, topographic exposure, and soil character. On a larger scale it may be related to climate, although in practice this has not always been so easy to determine as might be supposed; there was considerable debate, for example, as to whether the American prairies were an expression of severe climate or a cause of it! And in attenuated form, the de-

bate has dragged on long after the accumulation of scientific data had pretty thoroughly shown that climate is the antecedent rather than the emergent.

Once the reality of the plant community and its significance in relation to environment is clear, attention then turns toward the manner of its origin, its development, and the processes of interrelation which make it possible. In this is involved the study of life histories, individual requirements, competition, interdependence—in short, those aspects of individual behavior on the part of plants which, in animals, generally constitute the entering wedge of ecological study.

Whether investigation begins with animals or with plants, it ultimately encounters the fact that plants not only provide the food for animals but largely dominate, modify, and even delimit their environment. Although animals, being motile, may move from one plant community to another, in general the system of vegetation affords the best means of orienting them. On the other hand, animals play an important role in the community life of plants—as, for example, squirrels in the oak forest, wild bees on the prairie, etc. So true is this that we now recognize that the living community is actually a biological phenomenon, including both plants and animals.

All of this business of identifying communities in terms of the organisms which compose them involves labor in the field of plant and animal classification—

a technical task calling at once for profound and accurate scientific knowledge and great skill. False identification is worse than none. In actual fact few men, unless they devote a lifetime to a small area, are able to name accurately all of the organisms encountered in studying a community. For critical work the assistance of specialists is required. In addition to a considerable measure of skill in identifying the more familiar and frequently met organisms for himself, the ecologist must know where to find competent specialists and how to secure their assistance.

In the earlier stages of an ecological study, lists of species, perhaps with some notes on abundance, are enough. It soon develops, however, that except for the permanent vegetation, lists notably of insects and migratory animals made at various times of day and year do not agree. Moreover, one finds differences between the lists of organisms in different communities of the same general type.

At this point it becomes necessary to employ quantitative methods in community study. It is like the situation which arises when we learn that Cincinnati and St. Louis are German communities. To what degree is this condition true of each? To compare communities and trace the population changes within any one of them some methods of statistical comparison become necessary. Inasmuch as complete censuses are out of the question in large natural areas, the technique of sampling is used in one or more of its modifications.

Such, for example, are the various quadrat methods for sampling vegetation, sweeping, trapping, dung-counts, etc., for animals. Not only must the usual statistical safeguards be employed, but attention must be given to the nature and behavior of the organisms dealt with, and the practical ends to be achieved.

Presently problems arise as to the factors responsible for given differences. In some cases these may be fairly obvious, as for example, day and night, winter and summer, sand and clay. More often the relation is not so easily determined. Once again quantitative means must be used, this time in relation to factors of the environment—as for example, humidity or wind direction. Here the nature of the problem and the scientific judgment of the investigator must determine the means to be used; and often, repeated tests are necessary before the responsible factor, or—as is not infrequent—the group of factors, can be known.

Since ecology rests so largely upon observations that can be made in undisturbed conditions, it is important to note that such observations, if sufficiently precise and numerous, are an effective means of isolating the factor or complex responsible for a given situation. The process is essentially one of comparison and elimination. It is the principal method available for analysis within human communities and is important in medical research as applied to human beings, where experiments involving rigid control are not always possible.

Like any other technique, its success is a matter of the artistry and intelligence behind it. In ecology, quite often it leads to findings which can be experimentally tested. For example, sampling shows a relation between soil moisture and root development in the grasslands. Experiments can then be devised in which soil moisture is controlled and the effect on growing roots observed.

THE IMPORTANCE OF PHYSIOLOGY

At this point we encounter very distinctly the line of contact between physiology and ecology. Seeing a given relationship, we ask ourselves how the organism is fitted to prefer and sustain it? In the earlier studies along this line the answer to fitness was sought in the structures of the organism—succulence and thick skin in desert plants, fur and fat in arctic animals, evergreen leaves in the rain forest and in the taiga. Such studies were designated (among plants, at least) as ecological anatomy.

In this way many significant facts were developed. But a great deal of effort was necessary to get rid of crude teleological notions, based on an unscientific extension of the old idea of Special Creation. According to this view, the different kinds of plants and animals were regarded as specially designed to fit the varied conditions which exist over the earth. Even the acceptance of Darwin's Theory of the Origin of Species by Natural Selection did not completely clear up the

question of fitness, as there remained a strong tendency to read complete fitness into a relationship in which it was actually relative. Many remarkable characters may have little to do, one way or another, with fitness as such. The question can be answered only by critical experiment and observation. Such a proof involves investigation, first in the laboratory—a task for the physiologist—and second, if possible, in the field, or under ecological conditions.

Thus it comes about that the ecologist must lean heavily upon the physiologist for a knowledge of behavior, just as he requires the assistance of the taxonomist in identifying his material, and of the various sciences of earth and air for his attack upon the factors of environment. In a sense his approach is the most catholic, the least self-contained, of any of the biological approaches.

In consulting the physiologist, the ecologist asks him two sorts of questions. (1) How do you account for the presence of a given character? To what extent is it inherited, and to what extent is it a matter of response, during development, to peculiar conditions? (2) How does a given character behave in relation to particular conditions of environment?[1]

We might illustrate this problem with the tobacco plant. The leaves of Burley are much larger than those of Turkish, for reasons of inheritance. But Burley leaves grown in shade have a much more delicate tex-

[1] Blatz, William E. *The Five Sisters*. Morrow and Co., New York, 1938

ture—suitable for cigar leaf—than those grown in the bright sun. Again, Turkish tobacco will thrive in a drier climate (Colorado or Asia Minor) than the Burley (Tennessee or Kentucky), because large leaves evaporate moisture faster than it can be supplied in a dry climate. Again, the leaves of Burley which are thick and coarse from growing in strong sunlight will endure such light better than thin, shade-grown leaves suddenly brought into it. It is a simple matter to extend such illustration to other plants and to animals, wild as well as domestic.

Modern physiology becomes increasingly a matter of delicate physical and chemical determinations. This, however, does not indicate a less, but rather a more, intimate and effective relation to ecology. It makes possible a search for more obscure causes which may lie in the environment. For example, proper nutrition in certain animals may involve the presence of minute traces of essential elements in the soil, or a certain complement of amino acids from plants. The quality of light, or its periodicity, may be quite as significant to an organism as its intensity; in the earlier ecology only the latter factor was considered, and then only in relation to actinic rays.

The physiologist, faced with a living world of more than a million species, has, of course, explored the behavior of relatively few. These include man, certain of his domestic plants and animals, and certain species like the sunflower, the guinea pig, and the fruit fly,

which lend themselves particularly well to laboratory study. Concerning many which are of the greatest interest in nature, it is necessary to draw inferences, based upon work with the kinds just mentioned.

EXPERIMENTAL ECOLOGY

Such inference is, of course, not proof. Nor is it safe, ever, to assume that because a particular result has been obtained in the laboratory, the same causes operate to produce it in nature. The laboratory results are a guide, or a clue, often extremely valuable, but subject, nevertheless, to test in the field or under conditions simulating the field as closely as possible. This is the function of experimental ecology.

Ecology is a difficult and involved type of technique, which as yet boasts few workers and fewer masters. Like any technique, its application is a matter of artistry, nicely balanced to the problem in hand. The principle upon which it rests is largely that of wide-scale quantitative comparison rather than detailed quantitative control, as in the laboratory. A simple example is the transferring of an organism or a community into a variety of different environments, whose characteristics are recorded as completely and accurately as possible. If the transplant shows a particular type of behavior in certain of these habitats, the records are examined to ascertain in what respect habitat factors are alike, and how they differ in the remaining locations. The indications so obtained can

then be tested critically, either in the field or in the laboratory. It will be seen that there is thus a continuous interplay between laboratory and field, instead of a rigorous, mechanized sequence of procedure. The organisms exist in communities in the field. The problems of environmental relationship are often suggested there. The behavior involved must be analyzed in the laboratory, often suggesting further, specific problems in the field. The findings and explanations of the laboratory must be tested in the field, and such test may develop questions of a critical nature which again must be referred back to the laboratory.

If this procedure seems defective, let it be remembered that geology has progressed by an analogous course. Fossils are assigned relative ages by the position of rocks containing them. The knowledge so obtained is used to establish the relative ages of rocks whose stratigraphy may not be clear. Further fossil relationships may develop from such studies, and so the interplay continues. To the superficial critic of science this seems to afford an easy mark; but the method works, nevertheless, and so answers the critics.

In the sense just described, the task of the ecologist is never completed, even where he concentrates on a particular localized problem of adjustment. His quest is as unending as any search for finality, in any field of science. Moreover, he can never actually limit it to a particular time and place. Any situation he investigates is the expression of a past. Any type of com-

munity he studies is likely to extend, in some form or other, over a considerable area of the earth. And so, while he may find that given conditions of water, temperature, light, or minerals may explain the presence of a given community in a certain place, such an explanation cannot be assumed to apply everywhere. How does it happen that these particular organisms, so well suited to the conditions, are here on the spot? Where else are they to be found? Where did they exist previously, and under what conditions? How much have they contributed, or other organisms before them, to the conditions as they now are? And most significant of all, what is happening as a result of their present activity? As we have said elsewhere, "When he [the ecologist] enters a forest or a meadow he sees not merely what is there, but what is happening there."[2]

This, then, is the essential genius of the ecological approach—a struggle for perspective. The details of a given relationship are important, and their nature must be established by the most rigorous proof. But they must be given meaning as phases of a great genetic process in a frame of time and space. It is natural that some students of life and environment should be chiefly concerned with immediate relationships, others with the broader aspects. But the complete view cannot exclude either.

[2] Sears, P. B. *Deserts on the March*, p. 227. University of Oklahoma Press, Norman, 1935.

CHAPTER VIII

Ecology in the Service of Society

The Social Function of Ecology Is to Provide a Scientific Basis Whereby Man May Shape the Environment and His Relations to It, as He Expresses Himself in and Through His Culture Pattern

---

THE SOCIAL ORIGIN OF SCIENCE

SCIENCE, as we have seen, is a social institution. It has already transformed the material conditions of modern life. Society on its side supports the work of the scientist. The development of science has always been conditioned by the prevailing culture. Investigation in any particular period has taken its direction chiefly from existing needs, and has progressed or been retarded by the condition of existing cultural facilities—notably language, invention, and values. Kipling's imaginative story, "The Eye of Allah,"[1] describes the smashing of Roger Bacon's microscope in the thirteenth century by his religious superior, not from malice or ignorance, but because the prior, in his wisdom, knew too well the fatal unreadiness of society for it. It must be granted that Kipling gives this bit of

[1] Kipling, Rudyard. "The Eye of Allah"; from *A Kipling Pageant*. Doubleday, Doran and Co., New York, 1935.

fiction a nobler cast than most writers acquainted with the history of science might be inclined to give it.

In the realm of authentic history we have the report of Huxley, who when in Rome investigated at first-hand the persecution of Galileo.[2] He evidently found that a word or two might be said for the officials in that famous transaction. It is hardly to be supposed that the author of *Science and Christian Tradition* was taken in.

It is a favorite conceit of the man of science that he is the most independent of men, when as a matter of fact he is one of the most highly conditioned, in terms of the prevailing culture. His vocabulary and procedure are both extremely artificial—actually deliberate cultural devices—and so are his role and his freedom to work. So closely is he interwoven with the rest of mankind that his freedom and leisure can be secured only by an insistence on "pure science" or "science for its own sake." The pressure of practical men for immediate results which can be profitably applied cannot otherwise be offset. The history of experiment station publications in this country, and of science in current authoritarian societies shows this very clearly. The value of much work, its very scientific integrity, has been ruined by "practical" insistence. Some years ago, according to Herbert Osborn, the importation of useful parasites to meet a serious insect pest had to be

[2] Huxley, Leonard. *Life and Letters of Thomas Huxley*, Vol. 2, p. 122. D. Appleton and Co., New York, 1901.

held up for months until a highly theoretical treatise on wing venation could be completed. The work of Willard Gibbs at Yale, with its tremendous practical outcome in chemical industry, was pursued in an atmosphere completely detached from all practical concern; so useless did it seem that Gibbs's sister used him as a domestic aide to save her "busy" husband's time. Yet it must be remembered that Gibbs received his stimulus from a German professor in close touch with the active industrial life of that country. And, of course, the profits of commerce and industry furnished the endowment at Yale, under which Gibbs worked.

The spectrum of the sciences is familiar to all, ranging as it does from mathematics through the physical sciences on through biology to the social sciences. This represents not only the order of simplicity but the order of development and application. As the sciences become more complex, so does the problem of making them useful. The simpler sciences can be utilized through the medium of commerce and industry, largely on the basis of the profit motive. This is only partly true of biological science, which in the beginning owed so much to the search for industrial materials, the study of fermentation, and the need for control of disease in economic animals. Much of the current unrest in medical circles arises from the fact that problems of health cannot be dealt with completely on the basis of a profit economy. Medicine, so largely an application of biology (and chemistry), has extremely

important social implications which run far beyond the question of individual profit.

The application of the social sciences has proved to be the most difficult of all. Considerable use has been made of psychology in connection with selling, labor management, etc., on the basis of profit. But apart from such sporadic instances, there is little that appeals to individual business initiative. Moreover, except for applications of the principle of evolution and the use of biological analogies and statistical methods, social science has developed without much reference to the other sciences. Its material is the most difficult, its findings the most controversial. It cannot be impersonally applied. As soon as its results become socially significant they encounter cultural values, and so become matters of controversy. The final question, "To what end shall social knowledge be applied?" rests on intuition and feeling, not upon science, although in the end scientific method can do much to clarify both.

THE UNIQUE FUNCTION OF ECOLOGY

It is here that ecology can be uniquely serviceable. Ecology is the science of life and environment, including under the latter term both the inanimate and the living environment. In a sense it fills in the vacant triangle bounded by geography, biology, and sociology, giving perspective to all three. It cannot, to the same degree as the physical sciences, proceed without

taking into account social considerations. Its application is not confined, as that of sociology, almost wholly to controversial matters. It can make a beginning upon tangible, demonstrable problems having to do with the relations between man and his physical environment. It can even, as medicine does, bridge the gap between the profit motive and problems of the general good. This is particularly true when its findings are placed at the disposal of business groups such as investment trusts and life insurance companies with large land holdings, both of which are compelled to take a long-range view of their profit-making activities. There are increasing numbers of business organizations which are so conducted that their continuous prosperity must be assured; and increasingly those in charge realize that this prosperity depends upon that of a healthy and efficient community.

In the preceding chapters have been stated some of the more important scientific principles which ecology can provide for those interested in bettering the conditions of society. The dependence of man upon his environment for physical support may be taken as a primary fact. Unless his physical needs are met, other measures for his betterment are futile. There may be some question as to how far, after the essential needs are met, social betterment rests on the accumulation of further material facilities. Perhaps it rests more upon our better adjustment to the relationships, biological and physical, established in nature, and upon

the better adjustment of individuals to the general forms of human behavior.[3] But we may be content to leave that matter with the specialized field known as sociology, insisting meanwhile on the primary importance of maintaining such a relationship that the environment may steadily provide mankind with a sufficiency to meet its physical needs.

THE CONCEPT OF BIOLOGICAL POTENTIAL

The measure of the capacity of the environment to sustain living communities may be called its biological potential. The appropriateness of this expression arises from the fact that living communities are an expression of solar energy, arrested and elaborated through the activities of the living, instead of being immediately dissipated into heat. Life is analogous to a condenser, or an accumulator, or a dam which impounds energy in its course, enabling it to perform work before it proceeds to lower levels and so is lost. We are familiar with the figure which describes sugar and coal as bottled sunshine, but are less accustomed to regard all of human culture as a highly complex transformation of solar energy. The flowering of civilization on every continent is a measure of the degree to which tribute has been levied against the accumulated organic reserves, minerals, of course, being a valuable accessory not so directly related to solar energy. The

[3] Cf., in this connection, Russell, Bertrand. *Power*. Norton and Co., New York, 1938.

continuance of every civilization is measured largely by its success in establishing a working balance with the available supply of solar energy in the form of organic compounds.

Western Europe, since 1500, has drawn heavily upon the Americas as a source of biological potential, the latest and most terrific draft being during the war period of 1914–1918. One finds frequent mention of the importance of American gold in developing modern Europe. *But the importance of this gold lay in its use as an implement for the production and movement of organic material—hence of potential energy.* The fact that great prosperity obtained where furs and tobacco served as the medium of exchange shows that gold, however serviceable, was an incident. *And so I should say that the first, most essential, social function of ecology is to remind civilization of the physical basis upon which it rests.* One is led to believe, in reading a great deal of modern economics, that this task is not simple. It will not be done by catechisms masking as a study of life; it will require better and, I am convinced, more science instruction than is now available for the general student.

ECOLOGICAL DIAGNOSIS

Beyond this point, ecology can supply a technique for analyzing the character and trend of the biological potential of any community. This problem is, of course, tremendously complicated in a culture of highly spe-

cialized activities and ready intercommunication. Large cities cannot produce their own food or even maintain their own populations. Each draws upon a diversity of regions for its means of subsistence, and humanity demands an increasing production of nonessentials.

Yet the fact remains that the landscape is the source of organic materials, the visible means of impounding solar energy. And the landscape reveals quickly enough to the eye of the ecologist whether it is functioning effectively or not. One might suppose that this could be shown simply by statistics on the production of crops, wild or domesticated, plant and animal. This is the usual method of analysis, and the basis of investment and capitalization.

It possesses a fatal limitation, however, for it does not take cognizance of what is happening to the landscape as a result of production. The yields from newly turned earth are stupendous, but cannot be maintained at a consistently high level without increasing labor and expense. The relation between sun and earth is a continuous process, and there must be continuity in utilizing the landscape. The events of today are important in relation to what will happen tomorrow. Land management operates in cycles of decades and centuries. And on such a scale must it be scrutinized.

Conveniently, this scrutiny can be applied to four sets of factors in the landscape, closely related, it is true, but separable to a degree. These are, briefly, earth, water, air, and life, as enumerated earlier.

THE EARTH

The utilization of the earth depends upon its form and the degree to which it has developed a soil. In nature the topography is constantly changing, but as a rule such change is relatively slow, except on surfaces unsuited for use and under climatic conditions unsuitable for agriculture. Along with this slow process of change there goes the relatively more rapid process of soil formation, resulting in the presence of soil over a considerable proportion of the land surface. Thus, in a state of nature, constructive processes ordinarily maintain a net advantage over those which are destructive. Under the protection of natural vegetation soil tends to form faster than it is removed. The effect of this is to raise the biological potential to a maximum, so far as the earth itself is a factor.

At primitive technical levels, and under conditions of relatively sparse population, man does not seriously disturb this constructive process. But with the progress of invention and technical resources and the whole pattern designated as the "conquest of nature," man's power for altering the landscape is enormously multiplied and is quite generally exercised without reference to its ultimate effects. He removes the native plants and animals, establishing his own, under highly artificial conditions. This generally arrests the process of soil development, at the same time exposing the soil to the action of wind and water. Man with-

draws nutrient minerals from the soil without making return in kind. He establishes highways which introduce a new drainage pattern, often unrelated to the realities of topography.

Thus the net effect of his activities is to speed up the processes of surface change to such a point that not only do soil processes fail to keep pace but soil itself is stripped away, leaving the rock beneath exposed and burying the rich soil of valleys. Not only does he fail to maintain the biological potential where he found it; he actually decreases this potential. The work of man is thus antithetic to that of nature, a matter of reversal and conflict rather than of control. In many cases the upshot has been the abandonment of land, examples of which are to be found on every continent. In other cases an apparent balance has been achieved only because of the continued tribute of fertility brought in by streams. In a few notable instances a genuinely balanced and constructive relationship has been possible through the exercise of skill in managing, and restraint in drawing upon, the soil.

Technically, it is perfectly feasible to examine a given landscape and decide whether constructive or destructive change predominates. If the latter is found, we may be sure that the biological potential is decreasing, and with it the ultimate possibility of human cultural achievement. For culture, being the means of man's relationship to environment, is not a product of human society de-

tached from physical reality. To no small degree man's material achievement reflects the resources of the environment, as expressed in what we have here called its biological potential.

Thus the second explicit social function of ecology is to assay the condition of biological potential in a given landscape to see whether constructive or destructive change predominates. This is information of the greatest practical value to the social group.

THE WATER CYCLE

Turning now from the earth or lithosphere to the closely related hydrosphere, or world of water, we find ourselves dealing with a remarkable substance, intricately related to life. It constitutes a large proportion of the living body, is an ingredient of organic material, a solvent, and a dynamic factor in the shaping, as well as conditioning, of the environment. Thus the water balance, or the availability of moisture, is an exceedingly important social factor. Up to the point of an adequate supply, assuming other factors to be favorable, it determines the capacity of an environment to produce life, and thus affects the biological potential.

The distribution of water in nature is generalized in the hydrologic or water cycle. Water is evaporated from the seas and land, is moved about in the atmosphere, condensed, and precipitated. As it falls it may be held in the soil, may percolate through to the

water table below, or may run off. That which is held as capillary water by the soil is available, largely, for the growth of plants and other organisms, the amount available depending, of course, upon the physical character of the soil. That which percolates through serves as an agent in modifying the soil, but also forms an underground reserve which can be drawn upon in various ways to increase the abundance of life. Certainly a depletion of this reserve is disastrous to life. In moist climates the water table is in contact with the effective soil moisture above it and serves to recruit it. In arid climates there is often no direct connection.

The third fraction of the falling water, that which runs off, does the work of erosion and transport of materials. In natural conditions, as we have seen, this process is gradual, being retarded by the vegetation cover, and finding its expression in orderly drainage patterns.

Damage to the habitat from either a surplus or a deficit of water, from its too slow or too rapid removal, is at a minimum. It is clear that, once adequate and favorable drainage is organized, whatever increases the rate and amount of run-off lessens the amount of absorption and increases the rate of erosion. Both of these changes lower the biological potential.

It might be supposed that this decrease of potential would be compensated by the improved conditions in the streams and surface waters which receive the run-off with its load of material. Such is not the case, even

in the coastal waters of the sea. Light conditions are made worse, the chemical balance is upset, and the bottom is made unstable for anchored vegetation by the incoming silt. What is bad for the land as a habitat is bad also for the waters.

We have earlier described the usual effect of human occupation in speeding up topographic change. Very largely this result comes about by activities which decrease the absorption and increase the run-off of moisture. Vegetation and humus are removed, drainage is undertaken, highways are built, rivers are straightened and enclosed within levees. Whatever the immediate practical justification of such measures may be, the net effect is to shorten the time during which water is available for the use of living things, at the same time increasing the speed of its flow and hence its capacity for destruction. *Thus the third social function of ecology should be to analyze the course of the water cycle in any region, and to determine whether it is working toward or against a high biological potential.*

ADJUSTMENT TO CLIMATIC PATTERN

The evaporation, movement, and falling of water in its cycle are functions of the atmosphere, and among the most important aspects of climate, others being temperature, light, length of growing season, and wind movement. Many attempts have been made to classify the climates of the earth, on the basis of such records as we have. While the day-by-day activi-

ties of the atmosphere are of immediate importance, it is the atmospheric pattern, as manifested in climate, which is the basis of the broad pattern of living communities and of their capacity to produce life over long periods of time.

This is strikingly shown by various experiments in which yield has been correlated with certain limiting factors of climate. Such figures should be the basis upon which land valuation, in a general sense, rests. The usual practice, however, is to value land on the basis of its yields in most favorable years, without adequate allowance for the inevitable fluctuations.

That there is no simple formula for the classification of climates in detail is evident from an examination of the extensive study made some years ago by Livingston and Shreve.[4] Only in the broadest sense can climates be characterized in terms of rainfall, temperature, or simple combinations of both.

Unfortunately, the data on evaporation, which might be of great use, are scanty. This has led Thornthwaite to devise a formula whereby, if any two of the three—temperature, rainfall, or evaporation—be known, the third can be calculated.[5] He has thus calculated evaporation for hundreds of stations, and developed a second set of formulas for precipitation effectivity and temperature efficiency which can be integrated

[4] Livingston, B. E. and Shreve, F. *Distribution of Vegetation in the United States as Related to Climatic Conditions.* Carnegie Institute, Washington, 1921.

[5] Thornthwaite, C. W. "The Climates of North America." *Geographical Review,* Vol. 21, No. 4, pp. 633–655, October, 1931.

and used to characterize climate. As a necessary third element he includes the seasonal distribution of precipitation. On this basis he has classified the climates of North America and, more recently, those of the world, with results that tally remarkably with the pattern of natural communities.

Now the history of land utilization is full of instances of use and management which have failed because they were unsuited to the pattern of climate in space and time. It is well known that the farther any plant or animal is from its proper climatic home, the more care and expense are required to keep it going. It would seem silly to try to supply citrus fruits by growing them in northern greenhouses, but we frequently use subsidies to produce sugar outside of the tropics.

The net effect of such wrong adjustment to climate, whether the ultimate result is called failure or success, is to decrease the return in terms of human effort. Certainly the road to the maximum biological potential of any continent, and of the earth itself, is to have the most efficient adjustment between land use and climate. If, for example, a certain area produces good wheat crops in three years out of ten, with failures the other seven, is it wise to gamble on the odds? Is it right to plant wheat largely to the exclusion of other types of land use? This is quite apart from the demonstrated injury to the soil from such a procedure.

These remarks should serve to indicate the fourth social

function of ecology—namely, to supply data regarding the effect of climatic pattern and the extent of climatic hazard. In this way it can lend powerful and authentic support to other agencies working toward a rational and permanent relation between enterprise and environment.

NATURAL CLIMAX COMMUNITY EXEMPLIFIES BALANCE

Thus far we have discussed the problems of land use and management in the production of necessities from the land itself. The inanimate environment, land, water, and air, have been considered. There remains the living environment, the world of life, plants, animals, and man. Here we face a host of exceedingly complex problems, merging into the field of social science where our invasion is likely to be questioned.

We have seen, however, that the biological potential is influenced profoundly by the degree to which living communities consist of healthy organisms, effectively organized and making efficient use of the stream of energy at their disposal. The prototype is the natural climax community, adjusted to its environment by a long and rigorous process of selection. Such a community embodies trial and error far beyond the ordinary experience of scientific mankind, and deserves the closest study in every part of the world.

Natural climaxes should be utilized, insofar as possible, and methods of utilizing the climax com-

munity without destroying it should be much better developed than they are. A great stand of primeval hardwood from which trees have been removed only so fast as they mature would today be a priceless asset in any eastern state. During the disastrous drouth of the 1930's, it was a lucky farmer who owned a large stretch of unplowed virgin grassland in the West. If it were prairie, he could depend on getting hay, if short grass, pasture, when the plowed fields about him were yielding nothing.

Of course, civilized man cannot depend exclusively upon natural communities of plants and animals. He must clear and cultivate, in many cases completely replacing natural communities with those of his own making. And it is just here that an understanding of the natural climax community may be most useful. Not only is each new field and flock a community, but each is a part of the larger community, dominated now by man. For this larger community, the natural climax must serve as a model. The way in which the natural climax community maintains the soil and topography, its adjustment to local conditions, and above all, its favorable energy budget afford models which man must consider in his replacement of it with artificial communities of his own choosing. To the degree that these qualities may be simulated, he is likely to succeed. And if he disregards the lesson which they set before him, he will wear out his welcome on the land that he inhabits.

APPLICATION OF ECOLOGICAL LAWS MUST EXTEND TO ENTIRE LIVING COMMUNITY

It is not, unfortunately, enough for ecology to make clear the matters which we have just discussed. They must be made significant and effective in human living; they must be applied. Briefly, this application means the shaping of human culture forms into a condition of intelligent adjustment with the physical and biological environment. But this is hopeless without a workable adjustment of the relations of the individual to his human environment. Here, too, the fundamental laws of community development and equilibrium apply as in nature, modified tremendously by the intricate conditioned responses of which man is capable.

The community is not healthful unless the individuals who compose it are sound. It is not in good balance unless it is so organized that each individual is allowed a reasonably free opportunity to develop what is in him. Exuberance of one or a few at the expense of others is not good community dynamics, if we think of the community as a continuing thing. But this carries us over into the territory which the social sciences have staked out for themselves, and here the problem can be transferred to them. We shall only insist that they proceed to its solution fully aware that the processes of society rest upon the framework which we have tried to describe.

The fifth and final social function of ecology has thus

been indicated. This function is to point out the laws of community development and behavior in such way that they may be applied not only within the human community but to the wider community of living things with which man is integrated, and whose control he has assumed.

Appendix

Concerning Objectives. Use of the Foregoing Material in Teaching. Some Suggestions in Regard to Reading

I. CONCERNING OBJECTIVES

This volume, *Life and Environment*, has been written primarily for the use of teachers at secondary school and junior college levels, although the general reader has also been kept in mind. It is not intended to provide the basis for any new course of instruction so much as to give a point of view which should be useful in a large proportion of the courses now offered. For these reasons it is couched, so far as possible, in nontechnical language; if it is not clear to teachers and others who are not specialists in biological science, it must be revised until it is. At the same time it must meet the most exacting criticism of biologists from the standpoint of scientific validity; if it fails in this respect, again it must be revised until it is technically sound. No pains have been spared to meet both requirements in a concise manner. For reference to a somewhat more expanded and popularized discussion see Section III of this Appendix.

The occasion for such a volume as the present arises from the following facts. Biological science has necessarily developed by making use of analysis. The classification, structure, and behavior of living plants and animals have been studied by considering each subject as an end in itself, and by deflecting attention from the complex of related facts. For example, plants are collected and assembled in

the herbarium, or animals killed and preserved, later to be compared, classified, and named. Structure is likewise analyzed by dissection of the organism, and function studied by controlled experiments within the laboratory. All of these exceedingly fruitful procedures are necessary to verified, or scientific, knowledge. But all deal with the organism more or less removed from its natural environment and from participation in the living community of which it is a component.

While it is also true that naturalists, from the beginning, have made many observations on living organisms in the field, the organization of such material has been a comparatively recent problem of science. Ecology, the science of life in relation to environment, was christened by Haeckel in 1869, but the bulk of its technical literature has appeared since 1900.

Patterns of science instruction and information usually lag behind patterns of creative scientific work, often in biology by as many as twenty years. This is most likely to be evident in secondary schools and isolated colleges, but even in colleges which are part of larger universities the response to creative scientific work is more likely to be influenced by the special research interests of resident staff members than by any desire to achieve properly rounded courses of elementary instruction. Very generally, the interests of students who may specialize are paramount.

These facts are especially important to us because, unfortunately, ecology (the science of life relations) has few practitioners in the older institutions of learning. And it is these institutions which have had, and still exercise, the most profound influence upon scientific teaching throughout the country.

The importance of a knowledge of environmental rela-

tionships is not merely a matter of bringing teachers and the general public abreast of new scientific development, desirable as this may be. It is rather a matter of acquainting them with a phase of scientific knowledge of unusual significance to their own lives as well as to the lives of their pupils.

In any conception of education which extends beyond the acquisition of routine skill in various activities, a major aim certainly is to give the student a knowledge of the world in which he must live, and his relation to it.

This has long been recognized in practice, as well as in theory. But when Western education was chiefly under religious auspices the end was considered to be met by teaching traditional ideas about the origin and nature of the cosmos and man's place in it. Under the aegis of religion, philosophy, and ethics great stress was laid upon deductive interpretation of man's duties and relationship to the environment about him.

After the beginning of modern science, this traditional pattern persisted with astonishing vitality. Science, insofar as it might be taught for other than technologic ends, found its way casually and sporadically into curriculums as merely another type of "religious evidences." For this purpose one field of science might serve as well as another. Philosophy —in its various guises—was considered able to distill the essence from all fields of knowledge and present it in concentrated form to the busy student.

This might have worked but for the fact that science cannot be understood, let alone taught, by those who have not had a reasonable amount of direct experience with its materials. Insofar as science teaching is divorced from such experience it becomes merely a new sort of verbalism, dangerous enough at firsthand, but worse when passed

along to the inexperienced by one who himself has but verbal knowledge.

The single, or even several science courses from which the general student might choose were not organized or presented with a view to helping him acquire a world-picture based on sense experience. Those responsible were too often preoccupied, as we have said, with the needs of the student who might later become a specialist. The teachers were also commonly moved by a belief in the value of formalized training which could be transferred readily to other fields of experience. Between the various science departments, moreover, there was little conscious effort to dovetail teaching so that the student who took more than one science might be aided in building up a well-ordered world-view.[1]

Against this situation the recent interest in survey courses represents an inevitable reaction. These courses are still in the experimental stage; and frequently they appear to be handicapped, just as the old philosophy courses were, by too great emphasis on verbalism, without sufficient experience with the materials or working method of science.

Meanwhile, as we have indicated, the study of living things in their relation to environment (which obviously should form a basis for organizing a world-picture) has been developing as a science in its own right, i.e., *ecology*. Understandably (because it is a newcomer and has encountered the inertia of established forms of teaching) it is seldom represented either as an introductory science course or as a significant part of the newer survey courses.

If we are correct in our view that an understanding of the world and his relations to it is a major aim in the educa-

[1] Progressive Education Association. *Science in General Education*, Chap. I, Chap. III, p. 97. D. Appleton-Century, New York, 1938.

tion of the student, the objective of the present volume as far as the teacher is concerned should be clear. It represents an effort to organize some of the more important principles which underlie man's relationship to his environment. These have been drawn not only from the fields of animal and plant ecology but from the field which deals specifically with man himself, to wit, cultural anthropology. It is believed that the viewpoint here provided should illuminate the teaching of other subjects in the curriculum and assist the teacher to provide a nucleus around which the student can organize his own world-picture.

In presenting classroom material from the viewpoint of the present volume, the teacher is quite properly interested in measuring his own achievements in terms of the effects produced upon his pupils. This is known as the process of evaluation, represented by a substantial and growing body of technique. It is the first essential of this technique that the teacher formulate clearly the ends he wishes to achieve, in terms of student change. The responsibility for such formulation rests upon the teacher himself, yet it is possible that a few suggestions may be found helpful.

Frequently the objectives of teaching are stated in very general terms, such as appreciations, skills, sensitivities, and the like. Unless rigorously defined and circumscribed with reference to a particular situation, these are open to the objection of becoming ambiguous. Moreover, in using such terms, e.g., *concept measurement*, one is likely to run afoul of the rocks of conflicting psychological theory.

When such questions are likely to arise, it may be found most helpful to start by asking: "What sort of changes may I reasonably hope to produce as a result of teaching this material?" or "How may I reasonably expect students to show that they have done this work with me?" Following that, the teacher will be able to describe specific

situations to which the students might be expected to respond differently after the course than before. If we can do this, the task of the evaluator becomes relatively simple, so far as testing the degree to which the teacher achieves his objectives is concerned.

With these very simple considerations in mind, what are some specific ways in which an improved understanding of the relations of living things might be expected to show?

1. Verbal knowledge—ability to define such terms as:

   living community
   succession—in relation to: plants
   animals
   human culture
   equilibrium
   food chain
   nutrient cycle
   culture trait
   culture pattern
   soil profile
   atmospheric factor
   biological factors
   limiting factor
   stimulus and response
   life cycle
   population growth curve
   competition
   water cycle
   physiographic cycle
   succession
   climax

Closely involved is the ability to establish logical relationships among such words, recognize contradictions, and make deductions. Clarity and the ability to construct logical

verbal statements should accompany an understanding of the verbal equivalence of symbols used.

2. Verbal analysis of concrete situations—ability to:
    - Name the dominant organisms in a community observed
    - Designate the significant communities in the region
    - Designate the stages in community development
    - Designate the environmental factors operating on human culture in the region
    - Designate the steps by which human culture has modified the natural conditions
    - Designate the degree of adjustment of community life to: water cycle, soil cycle, climatic factors, etc.
3. Interpretation of symbols in terms of action—ability to:
    - Prepare a simple ecological survey map showing community types and locations
    - Interpret maps of weather, earthquake areas, hurricane zones, etc.
    - Find out an instance of: overgrazing
wasteful forestry
roadside erosion
good land use
    - Find: drainage patterns
truncated soil profile
normal soil profile
stream pollution sources

NOTE: In this and the following types of achievement, models of landscapes, etc., are a valuable and legitimate supplement to field work. Maps should be understood as conventionalized models in two dimensions and used as such.

Make a simple census—plant—animal—human

4. Action in terms of observed realities:

   Prescribe and design improved land use measures
   Examine a forest and designate trees for cutting
   Examine a stream and prescribe measures of improvement
   Examine and criticize some public project, e.g.,
      highway or park design
      wild life refuge
      irrigation or drainage project
   Select membership in an organization effective for solving regional problems
   Advocate legislation in terms of observed conditions

5. Less tangible but fundamental changes in behavior and outlook which might be expected.

These can be described only in general, indeed, vague terms. They represent the sort of things of which, in practice, we become aware through continued personal knowledge of people and which are likely to offer obstacles to any impersonal and routine testing.

Attitudes—e.g., acceptance of responsibility within the community to secure better adjustment of it to terrain, climatic risks, sewage disposal, forest and soil conservation.

Perspective—e.g., ability to view a local situation as part of a larger whole, to see events as part of a trend, etc.

Appreciations—e.g., use of leisure time, also vocational and economic interests. Synthesis of aesthetic attitude with action. Recognition of science as a means not only to practical ends but toward a desirable world-view.

II. USE OF THE FOREGOING MATERIAL IN TEACHING

We have stated in the section on objectives that the purpose in organizing the material for this volume was to provide a statement of a point of view which might illuminate teaching in many fields. And in the suggestions for standards of achievement which might be used in estimating the effects produced upon students, we have tried to make this statement concrete. Certainly an examination of the list at the end of the section will show a range of experiences and knowledge that extends out into many of the various divisions of the usual curriculum.

On the other hand, the scientific study of the interrelations of life and environment is essentially biological in its material, social in its significance, and heavily dependent upon the physical sciences in its technique. Insofar as it is taught as a separate discipline, it must be handled in connection with the biological work. Because courses in biology at the present time assign only minor importance to ecology and few teachers are trained in its methods, there is great need of definite teaching suggestions that can be utilized in modifying the present courses in biology. Important as this undertaking may be, the need for a general understanding of the ecological viewpoint as it may affect the teaching of all subjects is more immediate and will be treated first.

Perhaps the first consideration, applying to teaching in any phase, is the fact that it is not something done by the teacher to the pupil, but involves an experience in which both participate as members of a community. No doubt this would be conceded by most teachers without argument as a good working principle. In application, however, it is ex-

tremely difficult, despite the attention it has had in recent years. Modern schools are attempting a task never before seriously tried—that of general education of the general public. But for that task they are employing a type of organization developed largely as part of a much older social pattern. Military, feudal, and economic influences appropriate to a very different society from that of the modern world still persist in most schools. The undemocratic character of the average schoolroom has become a byword and, fortunately, a point of departure for new types of teaching practice in which the modern schoolroom becomes a community having some reference to the community at large.

A second point of general importance in this connection is closely related; that is, the importance of using the student's own community as a source of teaching material. One of the most frequent and damaging charges against those who teach in the schools and against their pupils as well is a lack of practical understanding of the realities of everyday life. This is probably not so much the result of a defective quality in the mind of the schoolman as it is an outgrowth of the traditional pattern which emphasizes attention to words and other symbols while neglecting experience with the things which they represent. Taking biology as a case in point, it is a common experience to find hard-pressed and underpaid biology teachers struggling through the elaborate symbolic treatment of heredity and evolution, using material from charts and books supplemented by dead type specimens preserved in alcohol and probably shipped in from long distances. Very often neither these teachers nor their pupils make use of the wealth of significant material and problems which are lying just outside the classroom door. A large measure of responsibility

for this rests with the taxpayer and his representatives. This illustration could be extended to such varied fields as civics, geography, history, and even the physical sciences.

Perhaps we can best show the possibilities of a new approach by discussing a setup in which it has been possible to make a fresh start. Let us assume that a group of teachers on the secondary or college level have been assigned the task not of teaching separate subjects but of collaborating on the work of acquainting the student with the local community, the larger regional community, and the world-community of which he is a part.

In such an undertaking there is not much doubt that the character of the community itself would have an effect upon the choice of emphasis to start with. Children from the professional and mercantile homes in an urban community might be most readily interested in approaching the problem through a discussion of social phenomena. Children from the homes of artisans and mechanics in an industrial area are likely to be more intrigued at the outset by the physical sciences and their application. Farm boys and girls as a rule have a background to make them interested in the biological sciences suitably taught. Clearly the character of the groups and even of the individuals is a matter which should be given attention at the outset.

In such an ideal system of collaboration the direction of movement should be from the immediate, local, familiar, and tangible to the more general and the more remote. In other words, upon an understanding of the local community should be built a picture of the region of which it is a part. From this region as a source the instruction should proceed until it encompasses the world-community. Let us consider, for example, the part played in such a scheme by a teacher trained in history and the social sciences. In many

states today there are requirements concerning the teaching of local history. If one examines such instruction he usually finds that it is a chronology of names and dates. It is likely to overemphasize the parts played by individuals more or less accidentally caught into the stream of events. It certainly overemphasizes the part played by artificial political boundaries. It seldom makes clear the relation of such local history to climatic and other geographical factors, to the larger trend of events elsewhere, or to the actual cultural processes involved.

In this field alone there is a marvelous chance to break down the rigid divisions, not only between the social sciences and other fields of knowledge, but within the social sciences themselves. At the present time the student may take a course in the history of his state and remain ignorant of events that have shaped his town or county. He will probably have a course in American history which seems quite detached from what he has learned about his state, and courses in European or world history which again have little to do with either. What student in Iowa, for example, is enabled to see Caesar's bridge cross the Rhine, the Roman roads in Britain, the perfection of the mariner's compass, the building of the Erie Canal, and the movement of great railroads across his own state as all parts of one great cultural process?

Something might be said also of the social sciences other than history. These at present face many difficulties. Economics, for example, is sometimes concerned with the conventions of exchange rather than with the environmental realities to which they apply. It lends itself with equal readiness to those who would rigidly maintain and those who would completely replace our present institutions. It can easily become preoccupied with the study of

mechanisms rather than relationships and with theories rather than the realities which give rise to them. Sociology is greatly concerned with pathological relationships in society, and until recently, has left out of consideration much of significant knowledge which the anthropologist has discovered concerning the nature of normal social relationships and processes. The opportunity exists in these fields to relate them to the local community, the region, and the still larger community of mankind.

Geography is rapidly escaping from its preoccupation with the trivia of political boundaries and the incidental designation of place. It has led in the development of an understanding of the regional relationships of culture. It still suffers, however, from outworn conceptions of race difference and from its divorce from history. As much as any other field of knowledge in the curriculum, geography needs to be presented not as a separate subject but as a means of illuminating the social and biological sciences.

The biological sciences, naturally, have a great responsibility in a program of the kind which we are discussing here. There is, however, at the present time a serious shortage of teachers who could participate in it. On them will fall responsibility for acquainting the student first of all with the living plants and animals of his region, both native and domesticated, and with the factors in the environment as they relate to the human animal. In learning the living organisms of the area it is less important that the students become acquainted with large numbers of species than that they become familiar with the common kinds and be able to recognize the communities of which they are a part.

Here again constant reference must be made to the fact that the present cannot be understood without a knowledge

of the past. The most significant thing today in explaining the pattern of plant and animal communities throughout America is the influence of the white man upon them. Working backward from the present disturbed conditions or ahead from an adequate picture of the original communities, the student should become able to trace the changes wrought by man and the influence which this process in its turn has had upon social developments within his own community.

Such studies afford a natural means of transition from his locality to the region of which it is a part. Suppose he lives in an area originally occupied by oak and hickory forest. Where else is this community found? How far does it extend and in what directions from his own locality? What are the climatic and soil conditions which account for it? What are the biological relations with animals and other organisms which characterize this community? How has it developed? Does it have a counterpart on other continents? What influence has it had upon industrial, commercial, agricultural, and social processes? These are but a few of the many instances in which biology could be made a living part of such an approach as we are trying to describe.

At the present time biological instruction is largely preoccupied with what might be called the formal or symbolic demonstration of the evolutionary theory. It is far more important to understand and emphasize the great framework of relationships and change of which evolution is one expression.

Coming now to the physical sciences, these subjects can be used to great effect as a means for measuring and explaining the complex of local environment which gives the locality its special characteristics. The physical sciences can also be utilized to advantage in a study of many local in-

dustrial activities, such as mining, power distribution, transportation, and chemical industry. These subjects at the present time do make considerable use of their relation to applied science, but not with much reference to the pattern of human activities on the earth.

In addition the physical sciences can be made an important agency in emphasizing the continuity of the operation of natural forces over the earth. This is quite as important as an understanding of the variations of physical and chemical conditions from one place to another. The fact that iron will rust and water will freeze on one continent as readily as on another has implications which can be skillfully used in extending the student's interests from his own locality to the larger world-community.

It should be emphasized again that the foregoing remarks are not intended as specifications for a program but merely as suggestions of what is possible. Also it should be emphasized that any program of this sort must rest upon an organization in which each teacher is thoroughly aware of what the others are about, and in which the subject matter divisions are forgotten except insofar as each teacher will use his special knowledge and training to contribute to the desired end.

In view of these facts, it is of interest to note that in some of the progressive education schools considerable advance has been made in utilizing the local community as a source of teaching material. It is, in fact, not a new device but one which has been utilized in the past by skillful teachers in many fields.

The possibilities of such an emphasis in the construction of an entirely new approach to general education have, however, not yet received adequate attention. It is hoped that the preceding pages may assist in laying a foundation

that will invite the scrutiny of scholars and encourage the cooperation of those engaged in the shaping of educational policy.

III. SOME SUGGESTIONS WITH REGARD TO READING

The author has developed, in a less compact and more popular style, the viewpoint of this report in a book called *This Is Our World* (University of Oklahoma Press, 1937). The three sections of the book deal, respectively, with the pattern of inanimate nature, the pattern of living nature, and the pattern of human cultures.

The book referred to is, intentionally, neither documented nor indexed for reference, nor does it treat particularly of the relation of human culture to the individual's development, as dealt with by Plant, J. S., in *Personality and the Culture Pattern* (Oxford University Press, 1937). This latter topic does receive some attention in the companion to the present volume, entitled *Human Growth and Development*, not yet published.

Some idea of the amount of literature on the one subject of plant ecology alone may be gained from examining the set of over one thousand references listed in Weaver, J. E. and Clements, F. E., *Plant Ecology* (McGraw-Hill Book Company, 2nd ed., 1938). This book itself is well written and of great utility. It discusses not only vegetation but the factors of environment. By going through its list of references with some care, treatises which describe the characteristic plant communities of many regions of North America can be found. Some acquaintance with such communities in his immediate region is essential to the teacher.

The subject of animal relation to environment is im-

mense, as may be expected from the number of animal species. Much of this material is scattered, and much highly technical. The English book by Elton, C. S., *Animal Ecology* (Macmillan Company, 1927) is helpful, also Adams, C. C., *A Guide to the Study of Animal Ecology* (Macmillan Company, 1913), as well as books by Pearse, Chapman, and Shelford.[1] Shelford and Clements now have a book called *Bio-Ecology* in press, dealing with both plant and animal relationships.

Technical papers on the subject of ecology have been appearing in the magazine *Ecology* since 1920. Many of these articles are well written, readable, and of considerable general interest. *Ecology* is published for the Ecological Society of America by the Brooklyn Botanic Garden, Brooklyn, N. Y.

The subject of the inanimate environment is scattered through the fields of geography, geology, meteorology, and soil science, and their subdivisions. Increasingly, however, good geographies are becoming available, including much of this most pertinent material. Excellent studies have emanated from the Federal bureaus, for example, O. E. Baker's *Atlas of American Agriculture*, Reports of the National Resources Committee, and many others whose titles can be secured from the bureaus concerned or from the Government Printing Office. In those states whose Planning Boards have seriously accepted their responsi-

[1] Pearse, Arthur Sperry. *Animal Ecology*. McGraw-Hill Book Co., New York, 1926. *Environment and Life*. C. C. Thomas Co., Baltimore, 1930.

Chapman, Royal Norton. *Animal Ecology*. McGraw-Hill Book Co., New York, 1931.

Shelford, Victor E. *Laboratory and Field Ecology; the Responses of Animals as Indicators of Correct Working Methods*. Williams and Wilkins Co., Baltimore, 1929.

Allee, W. C. *Animal Life and Social Growth*. Williams and Wilkins Co., Baltimore, 1932.

bility, some excellent reports are available and constitute good source material. Certain states, such as Wisconsin and Michigan, have long given attention to the problem of land-use planning.

Recently there has been a commendable effort to unite the various state agencies dealing with the many aspects of conservation, and such united departments have interested themselves in the preparation of educational material. With no disparagement to other states, we may mention Wisconsin, Ohio, Tennessee, and New York in this connection.

Moving next to the field of human ecology, we find the problem of economical reading is still more difficult. J. W. Bew's volume, *Human Ecology* (Oxford University Press, 1935), and White, C. L. and Renner, G. T., *Geography, An Introduction to Human Ecology* (D. Appleton-Century Co., 1936) recognize the subject in their titles. Wells, H. G., *Experiment in Autobiography* (Macmillan Co., 1936) has something to say about the educational importance of this field; and Wells, H. G., Huxley, J. S., and Wells, G. P., *Science of Life* (Doubleday, Doran and Co., 1934) will be found stimulating and helpful.

The writings of Isaiah Bowman and many of his geographical colleagues are also first-rate human ecology.[2]

For a survey of the human cultural relationship, one may consult the modern anthropological writings, and in particular Ralph Linton's *Study of Man: An Introduction* (D. Appleton-Century Co., 1936) and Ruth Benedict's *Patterns of Culture* (Houghton Mifflin Co., 1934). One may observe the application of modern techniques to the study

[2] Bowman, Isaiah. *Pioneer Fringe.* American Geographical Society, 1931. *Geography in Relation to the Social Sciences.* Charles Scribner's Sons, New York, 1934.

of human communities in the Lynds' two books on Middletown,[3] the studies of Paul Landis in the Mesabi Iron Region,[4] and the study of Lorain by Frost.[5]

Further valuable material for understanding the current picture is to be had in Lewis Mumford's writings, most recently the *Culture of Cities,* and in two reports of the Brookings Institute, *America's Capacity to Produce* and *America's Capacity to Consume.*[6]

However important, reading is no substitute for experience and contact with trained workers. For this purpose the summer workshop idea, for the training of teachers in service, has much promise. Such workshops, however, must be managed with great skill, not developed too rapidly, and not worked under too great pressure. A notable experiment which has not attracted the attention it deserves is the Allegany School of Natural History, sponsored jointly by the Buffalo Society of Natural Sciences, the University of Buffalo, and the Allegany State Park Commission. This is a workshop organized to make a comprehensive study of the community, its plants, animals, and human beings. An account of its work and purposes will be found in its bulletins and should provide ideas leading to the establishment of similar enterprises in appropriate places elsewhere.

[3] Lynd, R. S. and H. M. *Middletown.* Harcourt Brace & Co., New York, 1929. *Middletown in Transition.* Harcourt Brace & Co., New York, 1937.

[4] Landis, Paul H. "Cultural Adjustments to the Mesabi Resources." *Economic Geography,* Vol. 11, pp. 167–172, 1935.

[5] Frost, R. B. "Lorain, Ohio: A Study in Urban Geography." *Ohio Journal of Science.* Vol. 35, No. 3, pp. 140–238. 1935.

[6] Also Mumford, Lewis. *Technics and Civilization.* Harcourt Brace & Co., New York, 1934.

Odum, H. W. and Moore, H. E. *American Regionalism.* Henry Holt and Co., New York, 1938.

Index